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SELECTED WATER RESOURCES ABSTRACTS
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1. Report No.

2.

3. Accession No. **W** 72-04296

4. Title

EVALUATION OF SELECTED EARTHMOVING EQUIPMENT FOR THE RESTORATION OF OIL-CONTAMINATED BEACHES,

5. Report Date

6.

8. Performing Organization Report No.

7. Author(s)

~~Sartor, James, Foget, Carl~~

10. Project No. EPA Program 15080 EOS 10/70.

9. Organization

URS Research Company, San Mateo, California

11. Contract/Grant No.

13. Type of Report and Period Covered

12. Sponsoring Organization

15. Supplementary Notes Federal Water Pollution Control Administration, Water Pollution Control Research Series, ~~No. 15080 EOS 10/70,~~ October 1970, 169 p, 58 fig, 40 tab, 47 ref

16. Abstract

Field studies of earthmoving equipment units were conducted to evaluate their use and effectiveness in restoring oil contaminated beaches. Specifically, operating procedures and cost estimates were desired, along with any useful design modifications. Previous beach restoration operations were reviewed prior to initiation of the field tests for information about the type of performance required. The field tests were then performed on each equipment/procedure unit to determine efficiency, flexibility, and performance characteristics under a variety of field conditions. Oil removal effectiveness was greater than 98% for all restoration procedures, with the highest effectiveness being achieved by a motorized grader and a motorized elevating scraper working in combination. On low shear strength beaches, flotation tires or steel-belted half-tracks on the motorized grader and a non-self-propelled elevating scraper with a tracked prime mover should be used. Conveyor screening systems can be effectively utilized to load oil-contaminated materials onto trucks for transport to disposal areas, separate oil sand pellets from clean sand, and partially separate oil-contaminated debris from oil-contaminated sand. Straw spread on the beach area, as well as kelp, seaweed, and similar debris presented no problem to the operation of either piece of equipment and could be readily removed by the scraper. Front-end loaders were demonstrated to have the least effectiveness for oil removal, and to remove the largest amount of material with the oil contaminated debris. Costs for removal of 0.5 gal per sq.yd. of oil from a beach tidal zone ranged from $108/acre for a motorized elevating scraper working alone, to $1540/acre for a tracked front end loader operating alone. (Lowry-Texas

17a. Descriptors

*Oil wastes, *Beaches, *On-site tests, Water pollution control, Laboratory tests, Viscosity, Screens, Absorption, Water quality control, Transportation, Tidal waters, *Operating costs, *Earth handling equipment

are reported.

17b. Identifiers

*Beach restoration, *Graders, *Scrapers, *Conveyors, Seaweed

Copy available from GPO Sup Doc
[illegible], $1.50 ; microfiche
from NTIS as PB 206 693, $0.95.

17c. COWRR Field & Group 05G, 08C,

18. Availability

19. Security Class. (Report)

20. Security Class. (Page)

21. No. of Pages

22. Price

Send To:

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Institution Texas Univ., Austin

WRSIC 102 (REV. JUNE 1971)

GPO 913.261

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EVALUATION OF SELECTED EARTHMOVING EQUIPMENT FOR THE RESTORATION OF OIL-CONTAMINATED BEACHES

by

URS Research Company

San Mateo, California

for the

FEDERAL WATER QUALITY ADMINISTRATION

DEPARTMENT OF THE INTERIOR

Program Number 15080 EOS 10/70

October, 1970

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price $1.50

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ABSTRACT

Research studies were conducted to evaluate the use of selected earthmoving equipment in oil-contaminated beach-restoration operations and to determine the cost and effectiveness of such equipment. Specifically, the objectives were to:

- Determine modifications and cost required to improve the capacity of selected equipment.
- Develop optimum operating procedures for each method.
- Determine, through field testing, the operating cost of each method evaluated.

These objectives were accomplished in two phases. Phase I: reviewed procedures utilized in previous beach-restoration operations, plus surveyed and evaluated commercially available earthmoving equipment. Phase II: full-scale tests to demonstrate the restoration procedures developed and to determine the efficiency with which each procedure/equipment item collects oil-contaminated material. The flexibility and performance characteristics of the equipment were tested under a variety of beach conditions.

The oil removal effectiveness was greater than 98% for all restoration procedures. The highest effectiveness was achieved using the motorized grader and motorized elevating scraper working in combination. The tracked front end loaders were least effective. On beaches possessing low shear strength, flotation tires or steel-belted half-tracks on the motorized grader and a non-self-propelled elevating scraper with a tracked prime mover should be used. Conveyor-screening systems can be effectively utilized to load oil-contaminated material into trucks for transport to disposal areas, separate oil-sand pellets from clean sand, and partially separate oil-contaminated debris (i.e., straw, kelp, seaweed) from oil-contaminated sand.

This report was submitted in fulfillment of Contract No. 14-12-811 between The Federal Water Quality Administration and The URS Research Company.

Key Words: oil spills, oil contamination, beach restoration, earthmoving equipment, costs and effectiveness

FOREWORD

This report summarizes research conducted by URS Research Company for the Federal Water Quality Administration, Department of the Interior, under Contract No. 14-12-811 during the period, August 29, 1969, through July 1, 1970. The work was performed under the direction of Mr. Myron B Hawkins, President of URS Research Company, and Dr. Franklin J. Agardy, Vice President and Director of the Environmental Systems Division.

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SECTION I

FINDINGS

Based on the efficiency with which each beach-restoration procedure collects or spills oil-contaminated material and on the overall production rates determined for

- Motorized graders
- Motorized elevating scrapers
- Front end loaders
- Conveyor-screening system;

utilized singly or in combination, the following findings are offered:

1. A motorized grader and motorized elevating scraper working in combination provide the most rapid means of beach restoration when oil penetration is limited to less than 1 in. For oil penetrations greater than 1 in. the motorized elevating scraper operating singly is more efficient. In addition, the use of motorized graders and motorized elevating scrapers working in combination, results in the removal of the smallest amount of uncontaminated beach material.

    (a) The optimum moldboard (blade) angle for the motorized grader, in which minimum spillage occurred while windrowing sand, was found to be 50 deg from the perpendicular to the direction of travel. At smaller angles the sand builds up on the moldboard and spills around the leading edge. At larger angles, the operator loses the fine control of the blade and has difficulty keeping a constant depth of cut.

    (b) Straw spread on beach areas is easily windrowed by the motorized grader and removed by the motorized elevating scraper. Removing straw directly with a motorized elevating scraper posed no problems.

    (c) Kelp, seaweed and similar debris do not interfere with the operation of either the motorized grader or motorized elevating scraper.

    (d) On beaches possessing low shear strength, both the rubber-tired motorized grader and motorized elevating scraper may become immobilized during the conduct of beach-restoration operations. For such beaches, flotation tires or steel-belted half-tracks on the motorized grader and a non-self-propelled elevating scraper with a tracked prime mover should be used.

    (e) The addition of the sand baffle plates to the motorized elevating scraper bowl resulted in the removal of a significantly smaller total amount of material in the course of removing a thin film of oil. This was due to a reduction in spillage around the edges of the bowl, which eliminated the need for additional cleanup passes -- passes which would be certain to gather additional extraneous sand. However, when straw was utilized as an oil absorbent, there was no significant difference in the pickup efficiency of the baffle-equipped motorized elevating scraper and the conventional unit.

2. The oil removal effectiveness was greater than 98% for all restoration procedures. The highest effectiveness was achieved through the use of the motorized grader and motorized elevating scraper working in combination. The lowest effectiveness was obtained with the tracked front end loader.

3. The interaction between the oil loadings employed during the test program and the various equipment types evaluated was minimal, i.e., the presence of the film of oil on the beach surface did not effect the ability of the equipment to pick up, cut, or transport the contaminated beach material. It is believed that this finding could be extrapolated to oil loadings several times greater.

4. Use of the cone pentrometer and the minimum cone index value for calculating equipment trafficability factors should be a part of the preparation of contingency plans for beach areas susceptible to oil contamination. It must be noted, however, that due to seasonal variations in beach composition, a beach may present a trafficable surface during one period of the year and not during another.

5. A front end loader mounted on a crawler tractor is the most inefficient apparatus tested. In addition, more spillage occurs with its use than with any other equipment. These results can be extrapolated (we believe) to apply also to bulldozers. If front end loaders are utilized, it should be in combination with motorized graders, thus minimizing the volume of material removed and increasing the cleaning rate.

6. A non-elevating motorized scraper will not operate efficiently on beach areas unless a tracked prime mover is used as the principal source of power or as a pusher to assist in loading. A thin cut is difficult to maintain, and excess spillage occurs when loading.

7. Beach-restoration operations on backshore areas become very difficult due to the looseness of the sand. Procedures for minimizing the oil contamination of backshore areas should be instituted at the first indication of a possible shoreline-pollution event. Under normal tide conditions, a berm or dike at the high-tide mark can prevent oil from contaminating backshore areas.

8. Conveyor-screening systems can be effectively utilized to: (a) load oil-contaminated material into trucks for transport to disposal areas, (b) separate oil-sand pellets from clean sand, and (c) partially

separate oil-contaminated debris (i.e., straw, kelp, seaweed) from oil-contaminated sand.

9. The mixing action that occurred in the cutting and/or pickup of a thin film of fresh oil and the underlying clean sand results in a uniform oil-sand mixture. Under these conditions, it is not possible, by screening techniques, to separate oil-contaminated sand from clean sand.

10. The cost of removing a thin film (0.5 gal/sq yd) of oil from a beach tidal zone ranged from $103/acre (with a motorized elevating scraper operating alone), to $1540/acre (with a tracked front end loader operating alone). These costs are based on a haul distance (to unloading area) of 500 ft and average equipment rental rates.

11. To evaluate the manpower and equipment costs associated with beach restoration operations, a review of recent oil-pollution/beach-contamination incidents was conducted as part of this study. It was quickly determined that there has been little to no effort directed towards the recording of data needed to accurately determine the cost and effectiveness of previous beach restoration operations. Generally, only overall costs have been reported, and costs associated with onshore operations could not be separated from the total costs.

A set of data collection sheets has been included in this report (see Appendix F) as an example of the forms to be used by personnel who become involved in future oil-spill incidents.

SECTION II

RECOMMENDATIONS

On the basis of the findings of this study, the following recommendations are offered:

1. The principal effort in this project was directed towards examining an oil-contamination situation in which oil penetration is limited to approximately 1 in. and towards the development of operating procedures and equipment required for the restoration of sandy beaches.

   It is recommended that further research be undertaken to develop beach-restoration procedures for situations in which:

   (a) Shoreline areas are contaminated with light crude oils, resulting in depths of oil penetration greater than several inches.

   (b) Shoreline areas other than sandy beaches are contaminated, such as marshlands, mudflats, rocky beaches, and riprap.

2. The ability of heavy construction equipment to operate on a beach without becoming immobilized due to the low-bearing strength of the beach is an important factor in the selection of beach-restoration procedures.

   It is recommended that further research be conducted to evaluate the relationships between trafficability factors as determined by "minimum cone index values" on a range of beach types, and the mobility of various earthmoving equipment.

3. The disposal of oil-contaminated materials (sand, straw, debris) removed during beach-restoration operations constitutes one of the major cost items in oil-spill cleanup. At Santa Barbara, some 4,000 truckloads of material were transported to disposal sites up to 25 miles distant. In this study, it was shown that screening techniques could be utilized to separate straw, oil-sand pellets, and other debris from sand; however, large quantities of oil-contaminated sand (not amenable to cleansing by screening techniques) are produced by an oil-contamination event. Research sponsored by FWQA is currently evaluating techniques for the removal of oil residues from sand.

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It is recommended that studies be undertaken to establish the technical feasibility, including the identification of those conditions which may possibly result in economic benefit, for the use of oil-spill residues (including oil-contaminated sand) in activities such as:

- *Road construction (binder material)*
- *Land fills*
- *Agriculture*

SECTION III

INTRODUCTION

BACKGROUND

An increasing hazard of contamination of the environment with oil has accompanied the worldwide growth of the petroleum industry. Since 1954, some 8,000 offshore wells have been drilled, with 8 resulting in oil blowouts and 17 in gas blowouts, the recent Santa Barbara Channel[1] blowout being the most serious. It has been predicted[2] that if offshore development continues to expand at the present rate and the frequency of accidents remains the same, 3,000 to 5,000 wells will be drilled annually by 1980, and we can expect to have a major pollution incident every year. Additionally, supertankers of the future will carry much more oil than that released by the rupture at Santa Barbara and by the grounding of the *Torrey Canyon*.[3]

The problem of beach contamination becomes severe in the case of large accidental oil releases at sea, such as that of the *Torrey Canyon* and Santa Barbara incidents. Complete removal or dispersal of the released oil at sea in these incidents was not possible, and very large oil slicks moved ashore, coating entire beaches up to the high-tide mark. Where oil absorbents, such as straw, had been broadcast on the oil slick at sea, as at Santa Barbara, the oil-soaked absorbent was also deposited on the beaches, rocky shores, and riprap.

Once the oil comes ashore, serious economic and ecological consequences may result. Oil contamination has an obvious adverse effect on recreational uses of beaches. Since in many situations complete removal or dispersal of oil before it reaches the coast will be impossible, effective beach-restoration procedures are needed.

Previous restoration methods have used excessive amounts of labor. The choice of a restoration method depends upon the economic and recreational value of the area and surface conditions and topography of the shoreline. Although various types of earthmoving, construction, and agricultural equipment have been utilized in beach-restoration projects, the equipment does not appear to have been utilized either effectively or efficiently, and little has been done to mechanize or systematize beach cleanup operations. Appendix A summarizes previous shoreline oil-pollution events and the shoreline restoration procedures utilized.

URS Research Company personnel have had extensive experience in the development of procedures for the decontamination of beach and land areas contaminated with radioactive fallout.[4-9] Although fallout does not have the same physical characteristics as oil-contaminated sand and debris, the requirements of complete removal of the fallout particles from beach areas pose a similar problem, i.e., removal of a thin layer of surface.

During these previous studies, the processes involved and means of improving the performance of earthmoving equipment were investigated. Many of these findings are applicable to the use of similar equipment for utilization in the cleanup of oil-contaminated beaches. The possible approaches to improving performance (and reducing cost) of selected equipment include:

- Modifications to equipment, such as addition of baffles, blade modifications, etc.
- Optimizing operational procedures, such as speed of operation, blade angles, depth of cut.
- Changes in operational procedures, such as use of conveyor-screening systems in combination with graders and scrapers.

OBJECTIVES

The objectives of this research study were to evaluate the use of selected earthmoving equipment in oil-contaminated beach-restoration operations and to determine their cost and effectiveness in removing oil-contaminated sand and debris. Specifically, the objectives included:

(1) Determination of modifications and cost required to improve the capacity of the selected equipment.
(2) Develop optimum operating procedures for each method.
(3) Determine through field testing the operating cost of each method evaluated.

SCOPE

The method and equipment selected to restore a beach contaminated with oil will depend upon the manner in which the oil has been deposited onto the beach and the type of beach contaminated. For the purpose of this study, the principal effort was directed towards examining two representative situations involving oil contamination:

I. Beach material uniformly contaminated with a thin layer of oil up to the high-tide mark and/or deposits of oil dispersed randomly over the beach surface. Oil-deposit penetration is limited to approximately 1 in.
II. Agglomerated pellets of oil-sand mixture or oil-soaked material, such as straw and beach debris, distributed randomly over the surface and/or mixed into the sand.

In both of the stated conditions the restoration involves: (a) the physical pickup of the deposited oil, oil-contaminated sand, straw, or other debris; (b) the separation (in some cases) of the oil-contaminated debris from clean, loose sand; and (c) the removal of the oil-contaminated materials to a disposal site.

The surface conditions and topography of the beach contaminated with oil will dictate the choice of equipment to be utilized and the operating procedure to be followed. Surface conditions can vary from a smooth, hard, sandy surface to rocky (shingled), irregular surfaces. The topography can range from long flat beaches to those that are short, scalloped, steep and undulating. The principal effort in this project was directed towards the development of operating procedures and equipment required for the restoration of sandy beaches. A discussion of several factors associated with sandy beaches that are to be noted during the planning of beach-restoration operations is given in Appendix B.

METHOD OF APPROACH

The objectives of this research study were accomplished in two phases, each comprised of several tasks as follows:

PHASE I

Task I

Review existing reports on recent oil-pollution incidents and other available information to determine:

(a) The magnitude of beach contamination (to estimate potential material-handling load).
(b) Probable situations to be encountered (i.e., uniform or non-uniform oil contamination, types and amounts of debris, etc.).
(c) Previous methods utilized in beach restoration operations.
(d) The range of characteristics of beach sands (particle size, cohesiveness, materials, occurrence of rock, etc.) and beaches (size, accessibility, etc.) of the U.S. that may be subject to oil contamination.

Task II

Review equipment performance and develop preliminary beach-restoration operations as follows:

(a) Survey commercially available equipment and obtain information on pertinent performance characteristics.
(b) Review and evaluate previously used beach-restoration methods and identify limitations of equipment utilized.
(c) Design candidate beach-restoration procedures and identify possible limitations of equipment.
(d) Specify possible modifications to the equipment to increase effectiveness.

Task III

Conduct preliminary evaluation tests to determine:

(a) Necessary modifications and cost of modifications to motor-grader blades and motorized scraper hoppers to minimize spillage.

(b) Effectiveness of various screening techniques for oil-contaminated beach material.
(c) Effectiveness of pretreatment methods to facilitate pickup of contaminated beach material.

Task IV

(a) Preparation of a test plan for the full-scale testing of the candidate beach-restoration methods.
(b) Preparation of a "Preliminary Manual for the Restoration of Oil Contaminated Beaches."
(c) Preparation of a movie film documenting the Phase I effort.

PHASE II

Task I

Conduct full-scale field tests to evaluate the operating procedures and equipment modifications selected in Phase I. Performance criteria measured for each procedure and equipment combination evaluated included:

(a) Efficiency with which each procedure/equipment collects or spills oil-contaminated material.
(b) The ratio of oil to inert material in the mixture collected.
(c) The cost per unit of oil collected and unit of beach material handled.
(d) Capability of the equipment to operate under a variety of beach conditions.
(e) Performance characteristics, at various speeds, blade angles, and depths of cut.

SECTION IV

PHASE I EVALUATION TESTS

Full-scale evaluation tests at three beach sites along the San Mateo County, California, coastline and laboratory tests utilizing scaled mock-ups were conducted during Phase I to determine:

(a) Means of applying oil and oil-sand-straw mixture to beach test areas.
(b) Performance information for the various classes of equipment to be utilized in the beach-restoration operations.
(c) Evaluation of conveyor-screening techniques for the separation of oil-straw-sand mixtures from clean sand.
(d) Necessary modifications to equipment to enhance performance for beach-restoration operations.

On the basis of the analysis of previously used cleanup methods, discussions with equipment manufacturers, and a survey of commonly available earthmoving construction and agricultural equipment, the following equipment were selected for evaluation in this study:

- Motorized graders
- Motorized elevating scrapers
- Front end loaders
- Conveyor-screening systems

A description of the experimental procedures and results obtained in the Phase I evaluation tests are described in the following paragraphs.

OIL-CONTAMINATION SIMULANT

The Phase I evaluation tests and the Phase II demonstration tests require that a "representative" oil-contamination simulant be prepared. The word "representative" means that the simulant will produce essentially the same conditions of contamination as an equal quantity of typical oils that might wash ashore.

Crude oil spilled at sea undergoes changes with time generally attributed to "weathering." This weathering effect is due to the combined influence of sunlight, temperature, and interactions of the crude oil with seawater and air through sea surface turbulence. The crude oil undergoes evaporation and oxidation and perhaps some polymerization.

If oil is in the water for an extended period of time, an asphaltic residue is left which may represent 15 percent of the original volume.[10] Laboratory weathering tests performed by URS Research Company on Alaskan crude, furnished by the Union Oil Co., resulted in a reduction of 5 gal. of crude oil to a residue of less than 2 gal. after 26 days of weathering. The tar lumps that arrive on many beaches are the result of such long-term weathering. The changes in composition of a heavy crude oil, typical of that found off the coastal areas of California, is shown schematically in Fig. 1. These processes, as described by Dennis,[11] resulted in six forms of possible beach contaminants. Emulsions have also been added to the schematic in view of their importance in the Torrey Canyon incident.

After a "spill" has occurred, the immediate response of the oil to the environment is the release of its volatile components. The degree to which these volatiles are given off largely determines in what form the beach contaminant will arrive onshore.

The effect of weathering on a crude oil was explored in this study by floating oil on the surface of salt water in shallow trays (20 ft long by 10 ft wide by 6 in. deep) for periods up to 26 days. Kinematic viscosity and water content were measured on samples of the weathered crude which had been extracted each day. The water content, given in Table 1, was measured by means of the Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials, ASTM Designation: D95-62. Water content of the weathered crude increased with time (Fig. 2), as did the accumulated amounts of crude oil that sank to the bottom of the sample tanks. The increase of water content may be important in both the sinking of the heavier components of crude at sea and the formation of water-in-oil emulsions.

Two types of emulsions can be formed during the weathering process, namely, oil-in-water or water-in-oil. The oil-in-water variety consists of droplets of oil which become stabilized by chemical action at their surfaces and then dispersed across large areas. Water-in-oil emulsions are formed from droplets of water enclosed in sheaths of oil and stabilized by various resinous and asphaltic materials natural in crude oil. The result is a sticky viscous mass that has been referred to as "chocolate mousse."

From the standpoint of beach contamination, the tendency of oil to form emulsions, especially water-in-oil emulsions, appears to be important with respect to its properties as a beach contaminant. It has been stated[12] that the "chocolate mousse" contaminant was particularly troublesome during the pollution of English beaches.

The kinematic viscosity of the Alaskan crude oil samples was determined by means of the Tentative Method of Test for Kinematic Viscosity, ASTM Designation: D445.[13] As shown in Fig. 3 and given in Table 1, the viscosity increases with increased weathering, indicating loss of the more volative components of the crude.

The principal sources of oil which may seriously contaminate a beach along the U.S. coast are offshore drilling operations and accidental spillages from ocean shipping. A discussion of sources of shoreline oil pollution is given in Appendix C. A survey of the types of crude most likely to be encountered in an oil spill along the U.S. coast revealed that they are highly variable in chemical and physical characteristics. Since it was

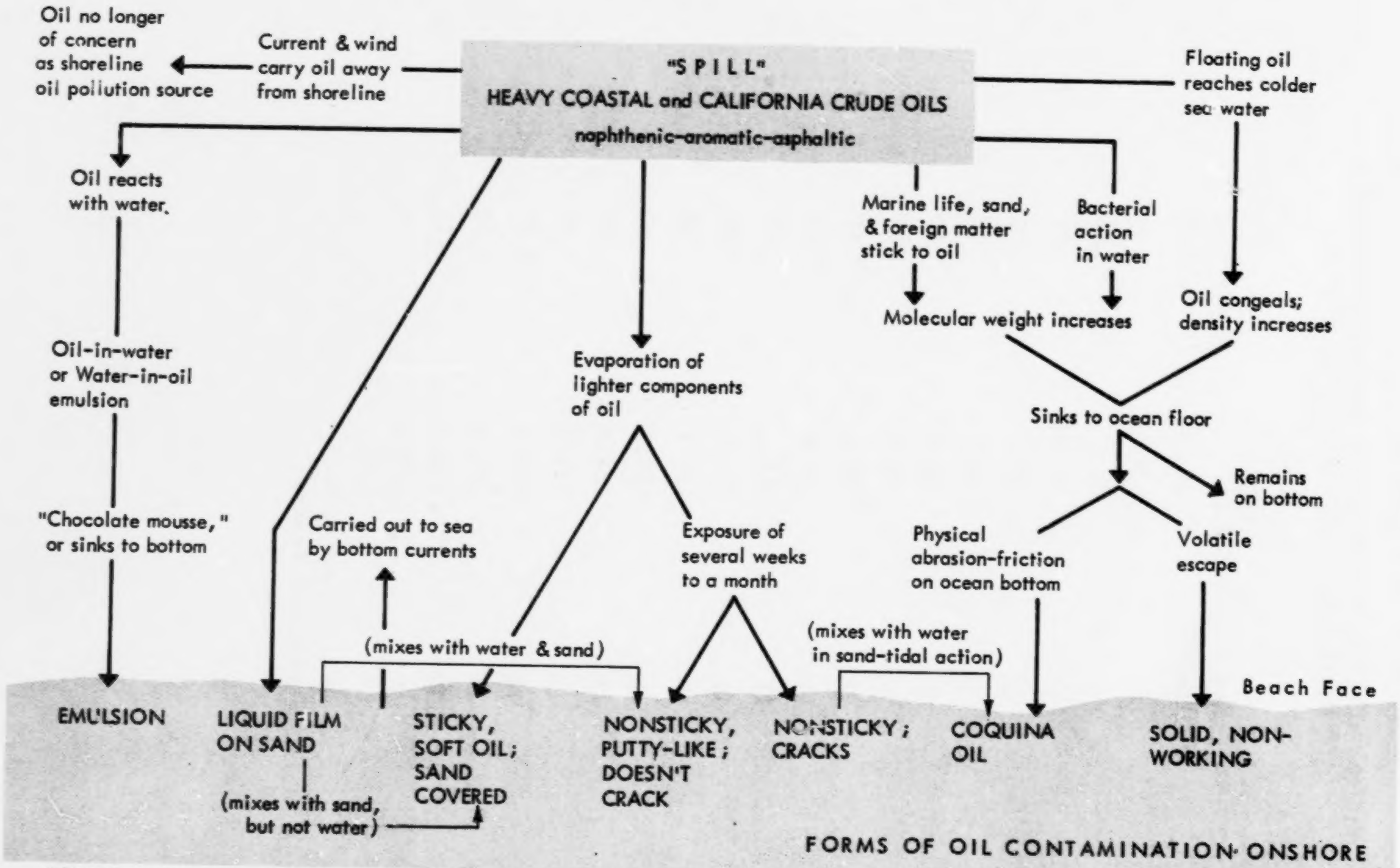
Table 1

KINEMATIC VISCOSITY AND WATER CONTENT TEST RESULTS OF WEATHERED ALASKAN CRUDE OIL SAMPLES

DAYS WEATHERED	VISCOSITY (centistrokes at 100°F)	% WATER
0	5.3	*
1	42.2	.05
2	54.3	.05
3	66.1	.06
4	68.1	.07
5	82.5	.10
6	88.8	.07
7	89.4	.10
8	97.8	.16
11	115.2	.09
12	113.8	.28
13	124.7	.18
14	118.7	.20
15	124.8	.35
18	133.6	.50
19	129.8	1.90
20	138.6	1.51
21	128.0	1.11
26	145.8	*

---

* Sample not tested


"SPILL"
HEAVY COASTAL and CALIFORNIA CRUDE OILS
naphthenic-aromatic-asphaltic
Current & wind carry oil away from shoreline
Oil no longer of concern as shoreline oil pollution source
Floating oil reaches colder sea water
Oil reacts with water.
Oil-in-water or Water-in-oil emulsion
"Chocolate mousse," or sinks to bottom
Marine life, sand, & foreign matter stick to oil
Bacterial action in water
Molecular weight increases
Oil congeals; density increases
Sinks to ocean floor
Remains on bottom
Physical abrasion-friction on ocean bottom
Volatile escape
Evaporation of lighter components of oil
Exposure of several weeks to a month
Carried out to sea by bottom currents
(mixes with water & sand)
(mixes with water in sand-tidal action)
Beach Face
EMULSION
LIQUID FILM ON SAND
(mixes with sand, but not water)
STICKY, SOFT OIL; SAND COVERED
NONSTICKY, PUTTY-LIKE; DOESN'T CRACK
NONSTICKY; CRACKS
COQUINA OIL
SOLID, NON-WORKING
FORMS OF OIL CONTAMINATION ONSHORE

SOURCE: URS Research Company, and Dennis.

Fig. 1. Schematic Diagram of Crude Oil Weathering.

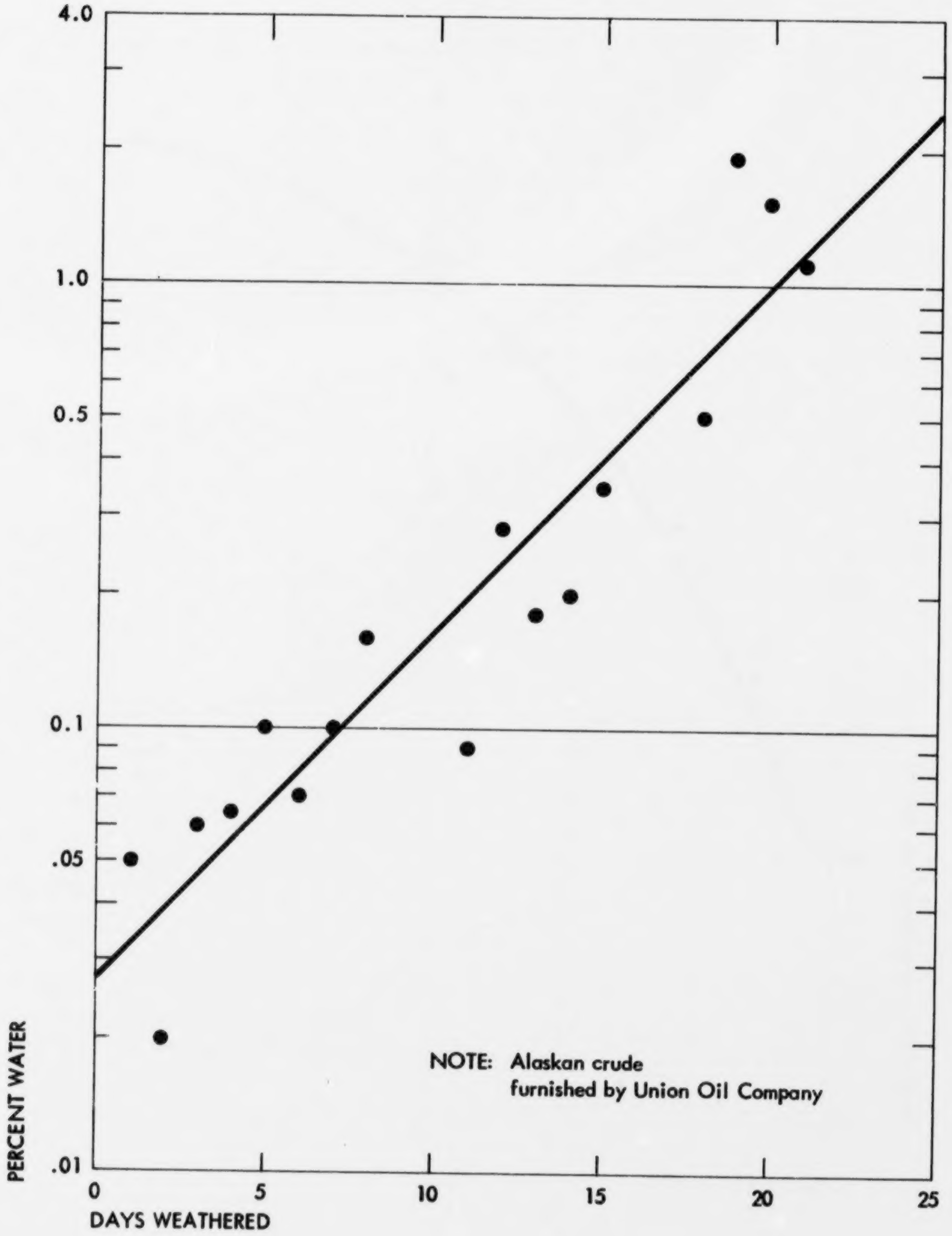


Fig. 2. Weathered Crude Oil Water Content

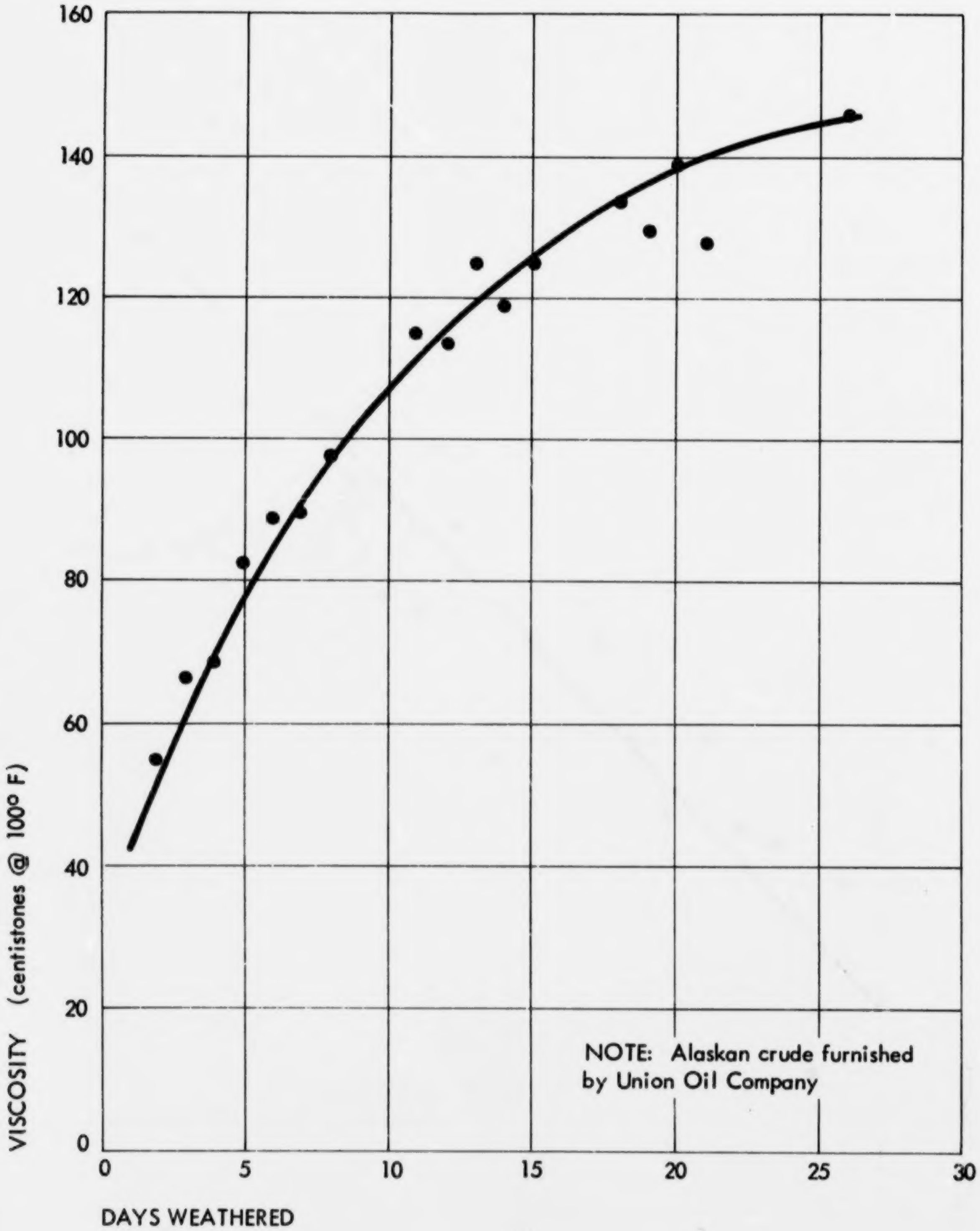


Fig. 3. Weathered Crude Oil Viscosity

not possible to use representatives of all crudes in the test program, it was decided to select one or two crudes having relatively common characteristics.

An Alaskan crude, somewhat similar to Gulf Coast offshore oils and to Cook Inlet Alaskan crude, was selected as one of the "representative" oils. Five hundrel gal. of this crude were made available by the Union Oil Company. The important characteristics of the Alaskan crude are given in Table 2.

Table 2

GENERAL CHARACTERISTICS
ALASKAN CRUDE

Source: Cook Inlet, Alaska (offshore)
Color: Dark green
Specific Gravity: 0.764
Gravity, ^{o}API: 53.7
Pour Point, ^{o}F: Below 5
Viscosity, Saybolt Universal at 100^{o}F: 29 sec.

COMPONENTS	% OF SAMPLE
Total gasoline and naphtha	69.0
Kerosene	10.3
Gas oil	11.2
Nonviscous lubricating distillate	3.6
Medium lubricating distillate	1.3
Sulfur	0.
Nitrogen	.005
Residium	1.7
Distillation loss	2.895

Source: Bureau of Mines

To properly prepare an oil contaminant requires that its properties duplicate the properties it would have upon floating ashore after a spillage at sea. As presented in Fig. 1, there are several modes by which spilled oil becomes a beach contaminant. In the absence of established statistical data regarding the elapsed time between the spill offshore and deposition on adjacent beaches, a weathering period of 1 week was used as an approximate median time for the weathering of the crude used in the Phase I evaluation tests. It was also assumed that the crude would arrive in the form of a liquid film. A series of weathering ponds were constructed, and Alaskan crude was floated as slicks on shallow ponds of salt water, weathered for 1 week, and then harvested and stockpiled for the test program.

Various candidate oil-spreading methods were considered as techniques that could be used to simulate crude oil washing ashore and contaminating a beach. Methods considered included:

(a) Spill a container of water and oil onto the beach test area.
(b) Spray oil onto wet sand.
(c) Spray mixed water and oil onto wet sand.
(d) Float the oil on offshore breakers so that it washes onto the beach.

Method (a) was selected for initial testing. The other three were temporarily set aside because of various deficiencies, such as: the process does not reasonably simulate the natural pollution process; the operation was mechanically too complicated; or adequate control of the crude oil during the simulated beach pollution would not be possible. Method (a) however has some of the characteristics of oil washed ashore by tidal action. The oil, floating on water, is deposited on the beach during the action of one "wave."

The method was field-tested on a beach test area. A plywood tank, 4 ft wide by 16 ft long by 1 ft high and lined with plastic, was placed at the high-tide mark, and filled with seawater 3 to 5 in. deep. The 16-ft side facing the ocean was hinged. When this side was dropped, the water in the tank flowed down the slope of the beach for 30 to 45 ft, depending on the depth of water in the tank and the degree of slope of the shore. Tests were conducted using 5 gal. of aged crude oil floating in the tank, and upon release, the oil was spread over a 300-sq ft area. Coverage was very uniform, with the oil penetrating the sand from 1/4 to 1 in. This method proved very satisfactory for simulating actual pollution events that would result in uniform coverage of beach areas by a thin layer of oil. Figure 4 shows the results of this oil-spreading technique. After release of the oil, straw or other oil adsorbers can be spread over the resulting oil film or these materials can be added to the oil while it is floating in the tank of water.

LABORATORY TESTS

The interactions between oil-contaminated material (i.e., sand, straw, debris) and equipment were determined in a series of scaled mock-up tests. In these experiments, a movable test bed containing a 4-in. layer of oil-contaminated sand was drawn under a quarter-scale motorized grader blade and a quarter-scale elevating system of a motorized elevating scraper. Figures 5 and 6 show the test setup.

The scaled mock-up tests of the motorized grader blade were conducted to determine (1) the optimum angle of blade for removing and windrowing a thin layer of sand, (2) the movement of the sand across the blade as it is cut and cast into a windrow and (3) the interaction between oil-soaked straw and the grader blade.

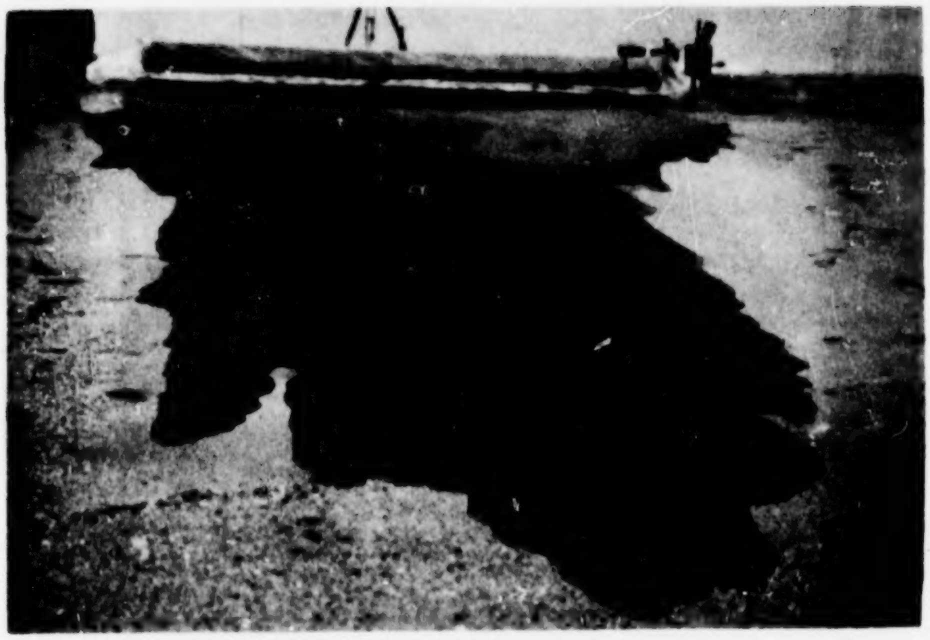


Fig. 4. Oil-Spill Test, Francis Beach, Showing Pattern Which Resulted

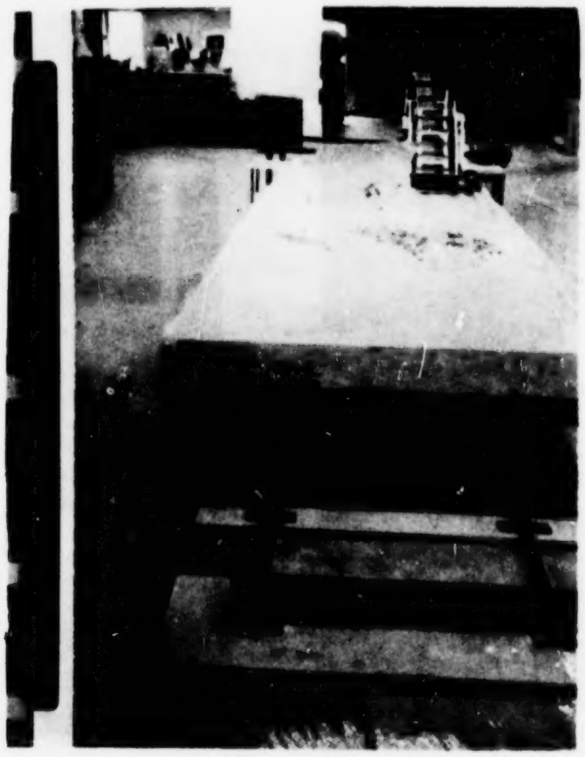
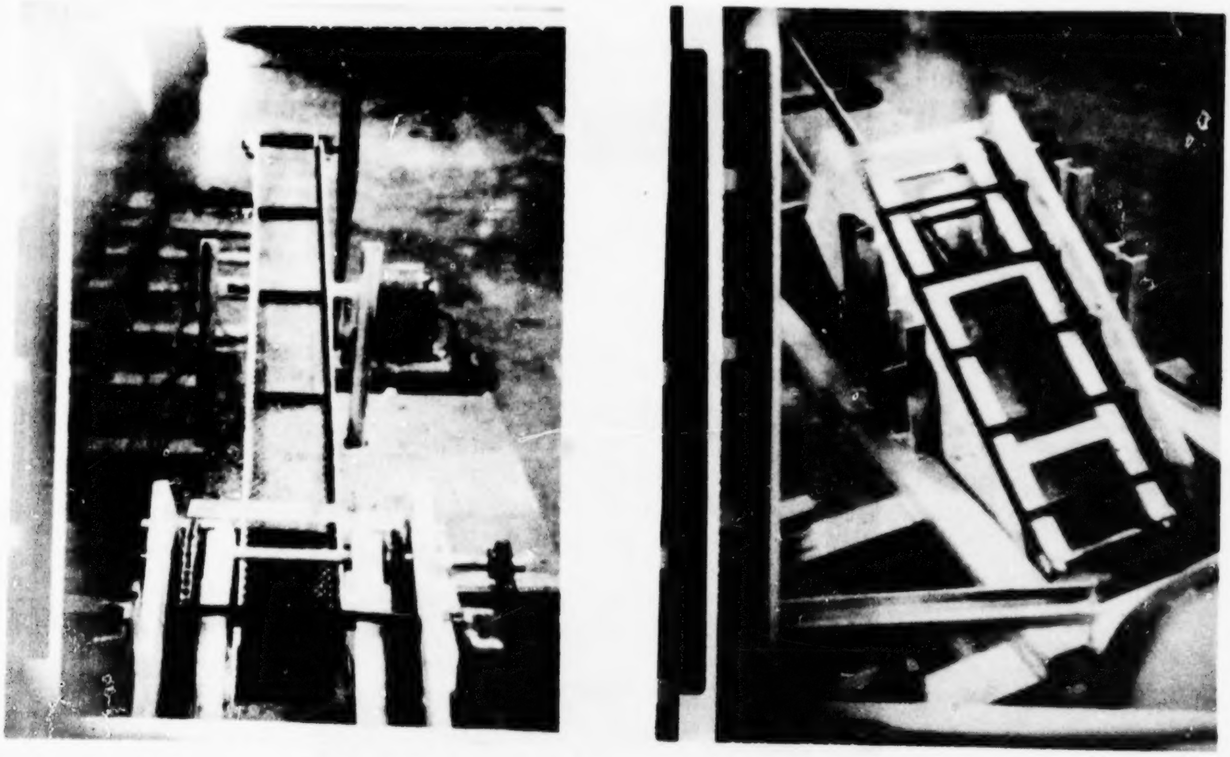


Fig. 5. Movable Test Bed

A. Scaled Motorized Grader Blade.



B. Scaled Elevating Scraper

C. Conveyor Screening System

Fig. 6. Quarter-Scale Mock-up System

The first series of tests performed utilized the scaled motorized grader blade set at various angles between 40 and 60 deg from the perpendicular to the direction of travel and with depth of cut varying between 1-3/4 in. and 1/2 in. Colored sand was used to trace the movement of sand from the leading edge of the blade to the resulting windrow. One group of tests was conducted with the traced sand placed, prior to cutting, at the leading edge of the blade; a second group of tests was conducted with traced sand placed 1 ft ahead of the leading edge.

In all tests, the height and width of the windrow created, the depth of cut and the distance down the windrow at which the traced sand first appears, were measured. A summary of the measurements is given in Table 3.

Table 3

QUARTER-SCALE MOTORIZED GRADER BLADE - DATA SUMMARY

Test No.[a]	Blade Parameters			Windrow		Initial Deposit (ft)
	Blade Angle[b] (deg)	Depth of Cut (in.)	Width of Cut (in.)	Height (in.)	Width (in.)	
1	40	1	30	3.50	11	11
2	47	1.75	27	4.50	12	8
3	55	1	25	3	11	6
4	58	1	25	3	10	5.25
5	45	0.50	27	3	8	8.50
6	50	0.50	27	3	8	7
7	55	1	24	3	10.50	5.50

a. Tests 1-4 with traced sand at the leading edge of blade.
Tests 5-7 with traced sand 1 ft ahead of leading edge.
b. Angle measured from direction of travel.

Figure 7 presents the results of the two groups of tests. As indicated, the best results were obtained when the blade angle was set between 50 and 55 deg. At these angles, the traced sand was placed in the windrow within the shortest distance from the point at which the sand was initially picked up. At blade angles less than 50 deg, excessive buildup

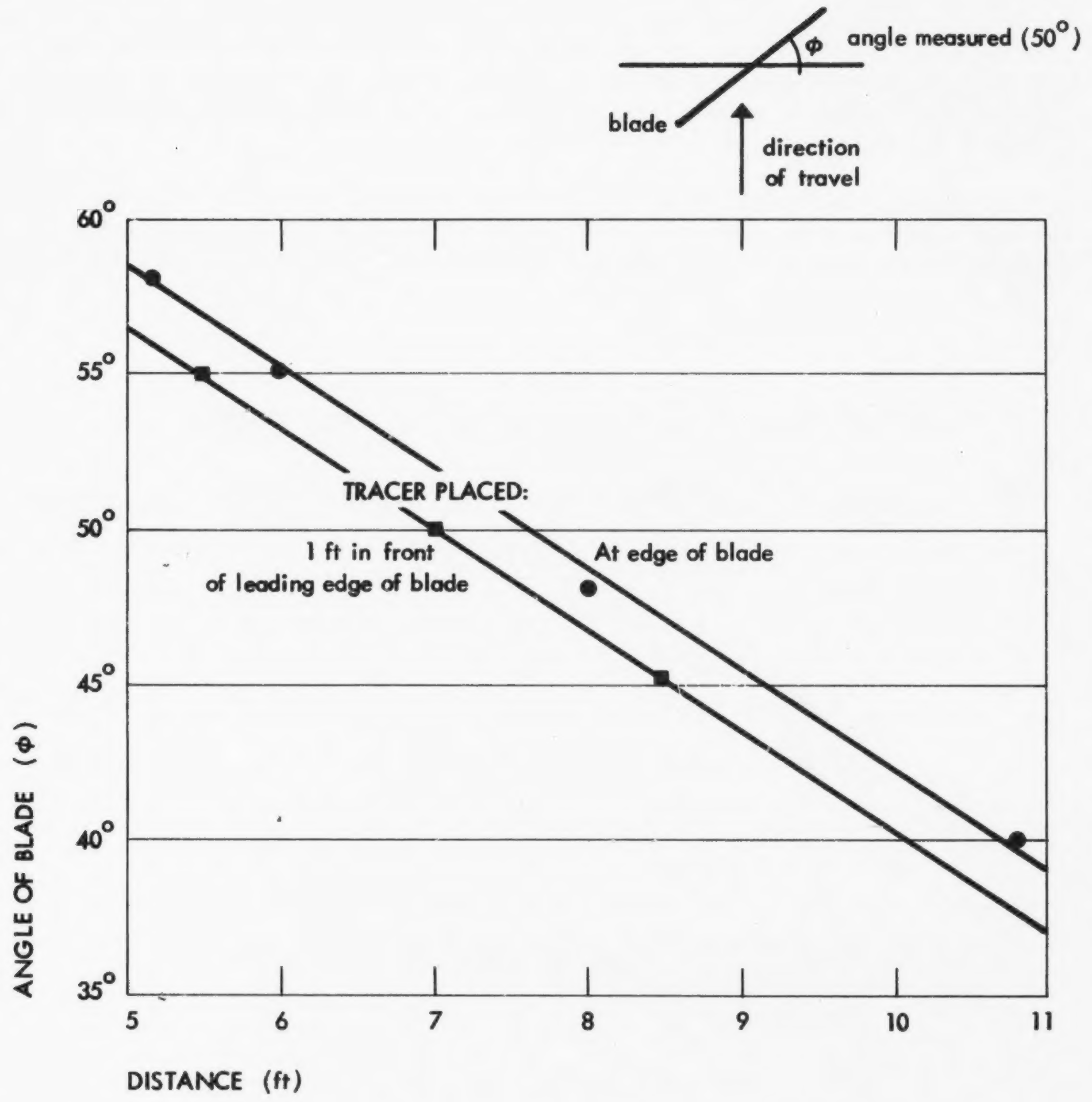


Fig. 7. Angle of Blade Versus Distance to Initial Deposit in Windrow

Table 4

RESULTS OF MECHANICAL ANALYSIS
(% of sample by weight)

BEACH	MEDIAN SIZE (μ)	SIEVE SIZE (μ)									
		> 2000	> 1168	> 701	> 495	> 351	< 351	> 147	< 147	> 74	< 74
Francis Beach*	540	.4	2.4	18.2	39.3	28.0	11.7				
Francis Beach**	455	.4	2.2	12.2	26.9	33.8	24.5				
Tunitas Beach, South**	248			.07	.68	.76		90.91		7.6	Trace
Tunitas Beach, North**	205			.09	.50	7.24		90.82		1.36	Trace
Half Moon Bay Harbor, West**	820		20.94	37.21	9.41	6.24		14.5	11.66		

---

* Backshore

** Tidal Zone

of sand occurred on the blade, which resulted in spillage of the cut material over the blade and around the leading edge of the blade. A motorized grader blade is normally set between 30 and 45 deg when grading to obtain a maximum width of cut for the movement of material. The results of the scaled mock-up tests indicated that greater angles are desired for movement of sand.

To determine the interaction between oil-soaked straw and the motorized grader blade, a test was conducted with oil-soaked straw placed on a test bed of sand. The scaled grader blade was set at an angle of 53 deg and at a depth of 1/2 in. As the windrow was formed, clean sand was mixed with the oil-straw mixture and the resulting mixture moved across the blade without adhering to the blade.

FULL-SCALE TESTS

Full-scale tests to evaluate the performance of selected earthmoving equipment were conducted at three beach sites along the San Mateo County coastline. The locations of these beach sites are shown in Fig. 8. The selection of the test sites was made after considering the following factors: (a) accessibility, (b) slope of beach, (c) sand grain size gradation, and (d) typicality (of recreation type beaches).

For each site, the average slope of the beach in the intertidal zone was determined. Sand samples were taken at various locations in both the intertidal zone and in the backshore area to establish the grain size gradation and the sand classification for each test site. The grain size gradation was determined by a standard sieve analysis, and the sand classification followed that established by the U.S. Department of Soil Conservation soil classification system. The results of the mechanical analysis are given in Table 4. A plot of these results and the sand classification for each test area are shown in Figs. 9 and 10.

A detailed description of each of the three beach test areas follows:

- Francis State Park Beach, Half Moon Bay, California — can be classified as a spit and baymouth bar type of beach and contains a coarse to medium sand with a median grain size of 0.54 mm in the backshore area and 0.45 mm in the tidal zone. The beach is loosely packed, has very soft footing, and a tidal zone slope of 6%.
- Tunitas Beach, San Mateo coastline — is an excellent example of a pocket beach and contains a fine to very fine type of sand with a median grain size of 0.25 mm in the backshore and 0.21 mm in the tidal zone. The beach is hard packed with very firm footing and has a tidal zone slope of 3%.
- Half Moon Bay Harbor Beach, Princeton, California — is located behind the breakwater of the Half Moon Bay harbor and can be classified as a spit and baymouth bar type of beach. The sand on the beach is poorly graded, varying from very coarse to very fine grain size and has a median size of 0.82 mm in the tidal

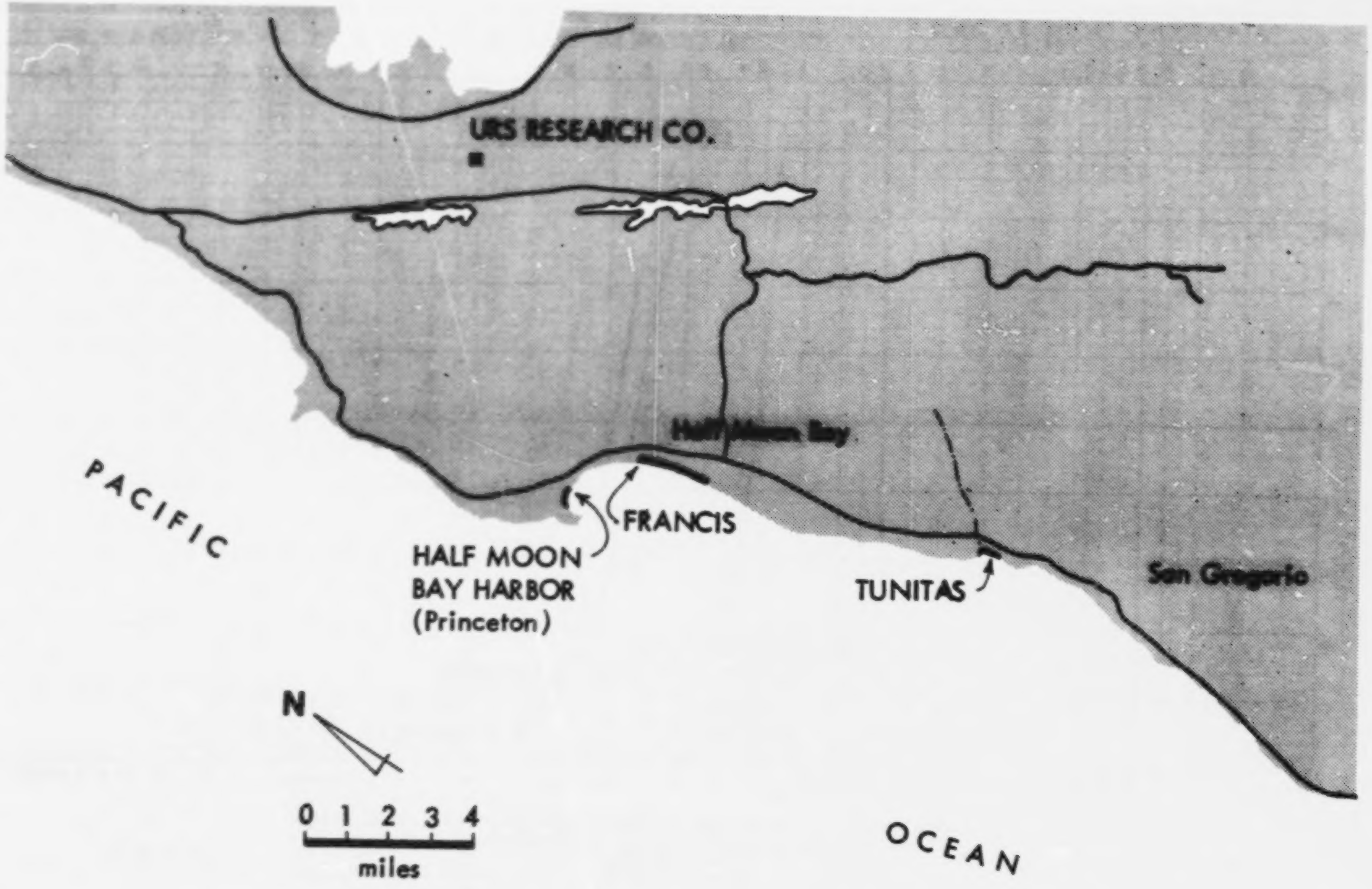

URS RESEARCH CO.
Half Moon Bay
PACIFIC
FRANCIS
HALF MOON
BAY HARBOR
(Princeton)
TUNITAS
San Gregorio
N
0 1 2 3 4
miles
OCEAN

Fig. 8. San Mateo County Coastline Test Sites

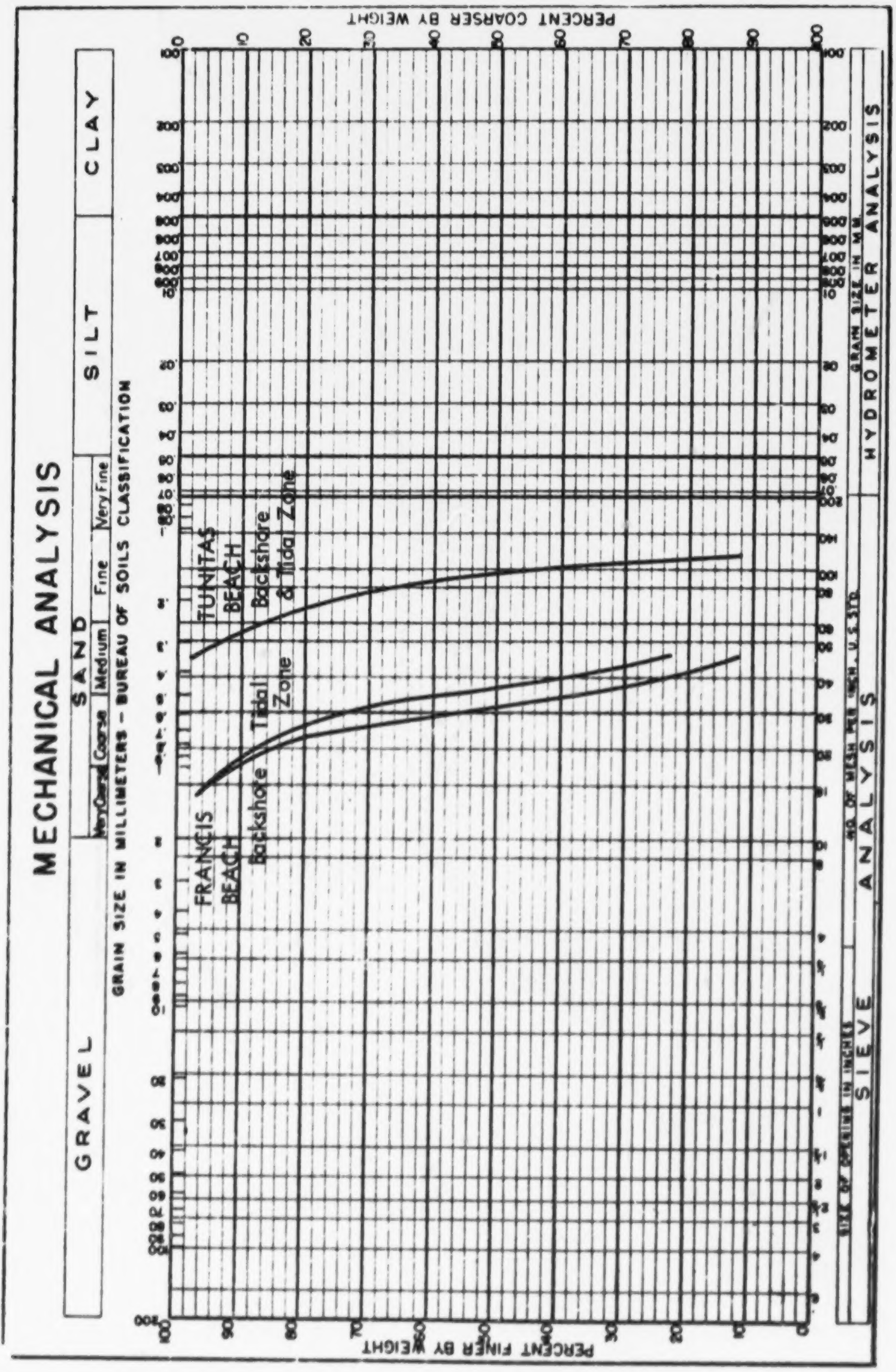


Fig. 9. Sand Classification for Francis and Tunitas Beach Test Area

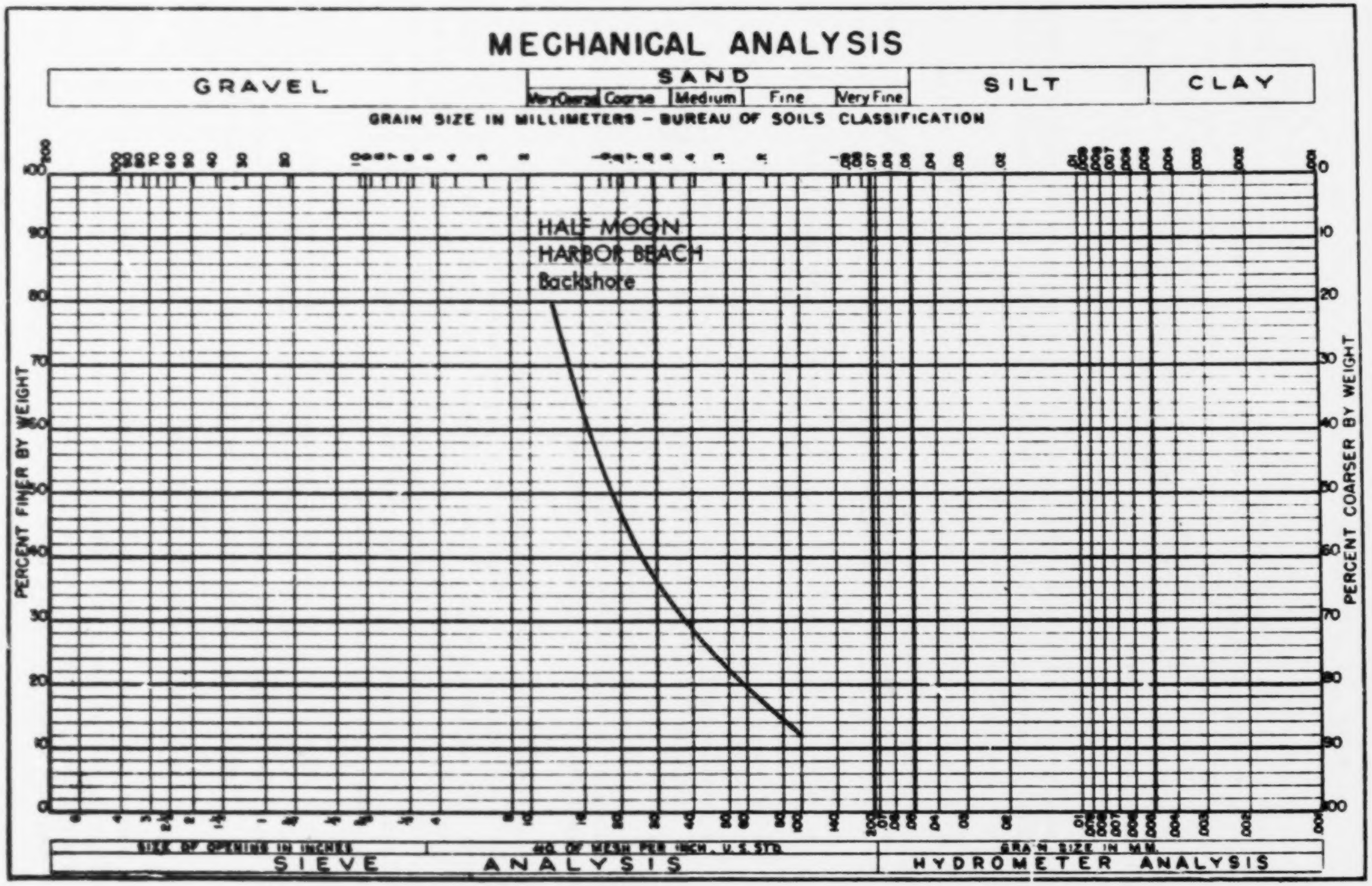


Fig. 10. Sand Classification for Test Area. Half Moon Bay Harbor Beach

zone. The beach has medium packed sand with medium to firm footing and a tidal zone slope of 3%.

All three beaches are used for recreational purposes. The Francis State Park Beach and the Princeton Beach are public beaches and offer ready access for heavy equipment. Tunitas Beach, a private beach, is located at the base of steep cliffs and an access road had to be constructed by widening an existing foot path. This was accomplished in 1 day's time with a bulldozer. These three beach test sites provided a range of characteristics that are representative of many beaches along the U.S. coastline.

Seventeen series of tests were conducted utilizing a motorized grader, motorized scrapers, and front end loaders, singly and in combination. The equipment evaluated included:

- Motorized Grader — (Fig. 11) Caterpillar Model 12, rubber tired, 12-ft blade, 115 hp.
- Motorized Elevating Scraper — (Fig. 12) International Harvester Model E-200, rubber tired, 9-cu-yd capacity, 135 hp, two-wheel drive.
- Motorized Scraper — (Fig. 13) Caterpillar Model 10, rubber tired, 12-cu-yd capacity, 120 hp, four-wheel drive.
- Front End Loader — (Fig. 14) Caterpillar Model 955, crawler tractor, 4-in-1 bucket, 1-3/4-cu-yd capacity, 115 hp.
- Front End Loader — (Fig. 15) International Harvester Model 175B, crawler tractor, 4-in-1 bucket, 2-cu-yd capacity, 120 hp.

The choice of make and model of equipment evaluated was determined only by equipment availability at the time of testing. These items, however, are representative of their classes.

Detailed specifications for each equipment item evaluated are given in Tables 5 through 8. To improve the performance on sand, the motorized grader was equipped with 23.5x25, 10-ply flotation tires on all four driving wheels in place of the standard 13.00x24, 10-ply tires (see Fig. 16). The motorized elevating scraper was also equipped with two optional features designed to improve operating performance on sand. These consisted of the following:

(a) The installation of a high-speed, low-torque motor cartridge kit to increase the elevator speed approximately 20%-29%.

(b) A transmission change consisting of a turbine and drive gear modification to reduce the ground speed from a maximum speed in first gear of 6 mph to 2.72 mph and a reduction in second gear high range from 24 mph to 16.6 mph.

The operating characteristics of each piece of equipment in removing the surface layer of sand was determined at each beach test site under different beach conditions as indicated in Table 9. In several tests, oil was utilized in tidal zone areas, and in one instance on the backshore

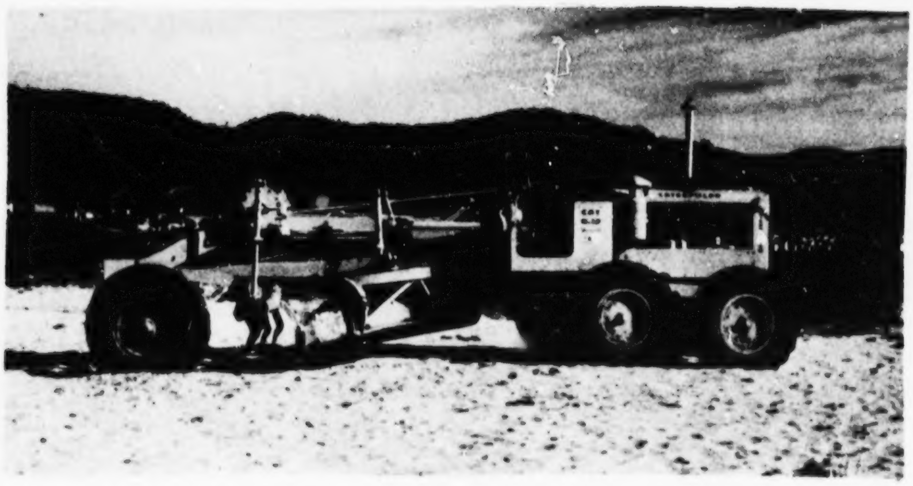


Fig. 11. Motorized Grader

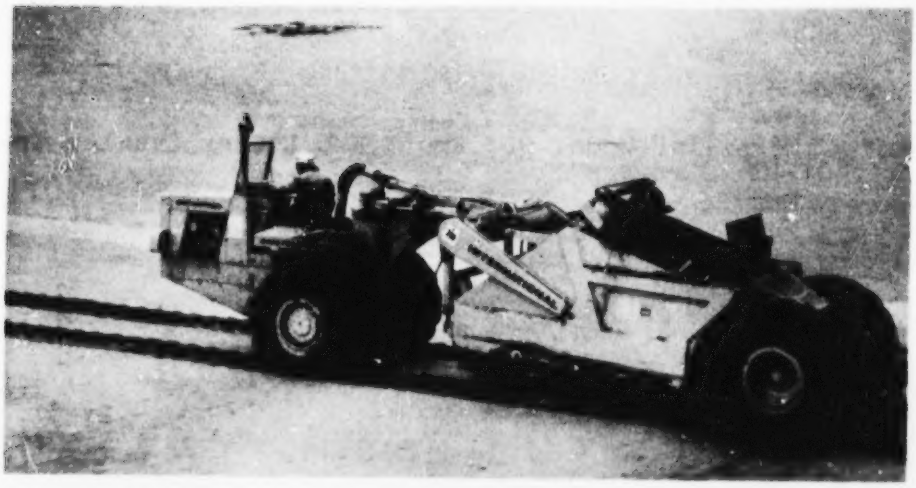


Fig. 12. Motorized Elevating Scraper

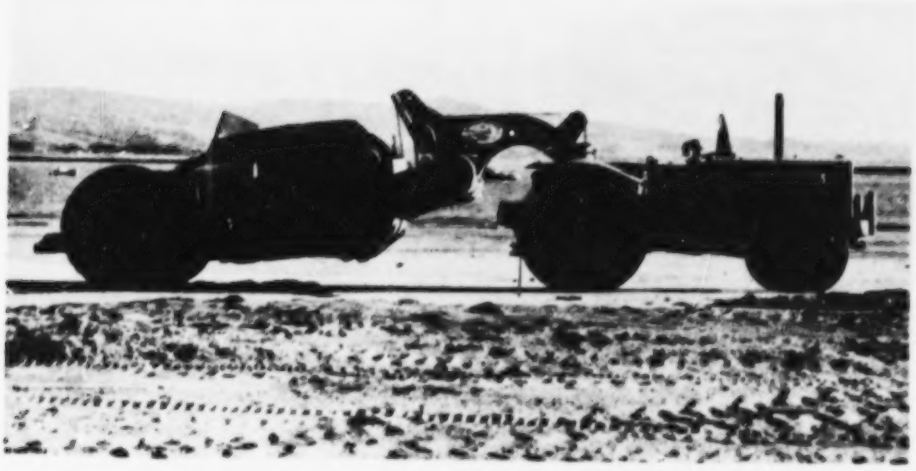


Fig. 13. Motorized Scraper

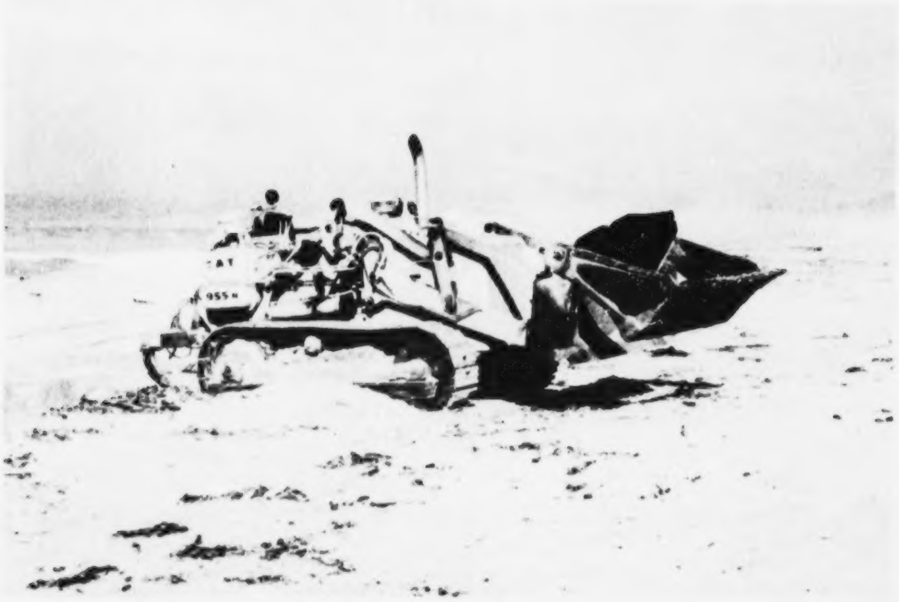


Fig. 14. Caterpillar Model 955 Front End Loader Crawler Tractor

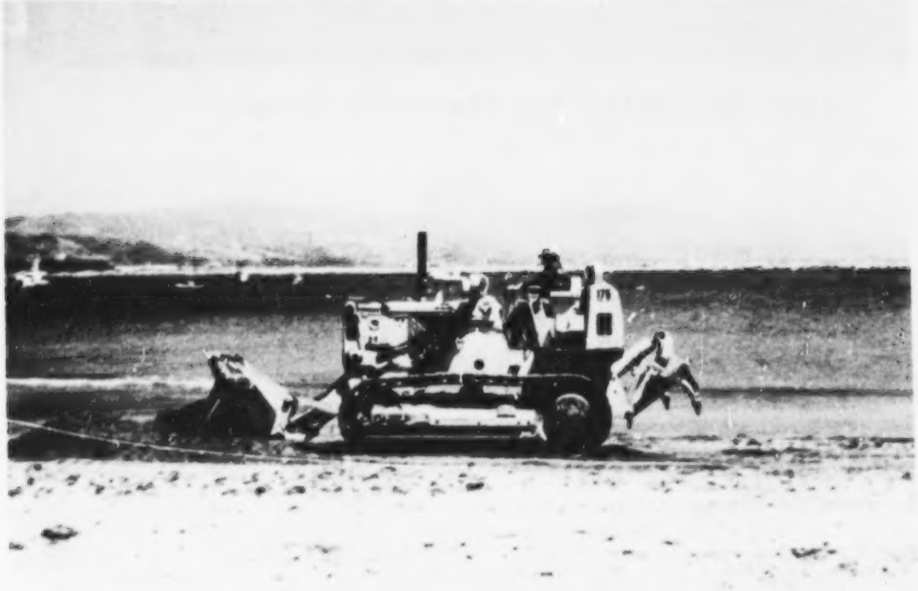


Fig. 15. International Harvester Model 175B Front End Loader Crawler Tractor

Table 5

DETAILED EQUIPMENT SPECIFICATIONS

CATERPILLAR 12
Motorized Grader

Blade	Length (ft)	12
	Height (ft)	2
Overall Dimensions (in.)	Height	125
	Width	84
	Length	322
Engine	Type	Diesel
	Model	D333
	Rated hp	115
	No. of cylinders	6
	Displacement (cu in.)	638
Transmission	Type	Direct drive
	No. speeds forward	6
	No. speeds reverse	2
	Max. speed forward (mph)	19.9
	Max. speed reverse (mph)	13.8
Shipping Wt. (lb)		26,700
Liquid Capacity (gal)	Fuel tank	75
	Cooling system	11
	Crank case	7.75
Tires	Flotation, 10 ply (4 driving wheels)	23.5x25
	Front wheels	13.0x24

Source: Caterpillar No. 12F brochure

Table 6

DETAILED EQUIPMENT SPECIFICATIONS

INTERNATIONAL HARVESTER E-200
Motorized Elevating Scraper

Bowl	Heaped Capacity (cu yd)	9
	Cutting Edge - Width (in.)	13
	Cutting Edge- Length (ft)	4.5
	Rated Load (tons)	11.25
Elevator	Length (ft)	9
	Chain Speed (ft/min)	216
	No. of Flights	14
Overall Dimensions (in.)	Height	109
	Width	96
	Length	390
Engine	Type	Diesel
	Model	DT-361
	Rated hp	135
	No. of cylinders	6
	Displacement (cu in.)	361
Transmission	Type	Power shift, constant mesh
	No. speeds forward	4
	Max. speed first gear (mph)	2.72
	Max. speed second gear (mph)	16.6
	Max. speed reverse (mph)	8.4
Shipping Wt. (lb)		26,200
Liquid Capacity (gal)	Fuel tank	47
	Hydraulic reservoir	31
Tires		23x25

Source: International Harvester E-200 brochure

Table 7

DETAILED EQUIPMENT SPECIFICATIONS

CATERPILLAR 955
Front End Loader - Crawler

Bucket	Heaped Capacity (cu yd)	1.75
	Struck Capacity (cu yd)	1.5
	Width (in.)	80
	Type	4-in-1
Overall Dimensions (in.)	Height	84.75
	Width	75
	Length (bucket on ground)	189
	Length (bucket in carry position)	--
	Track length on ground	85.25
	Width of track shoe	15
	Track gage	60
Engine	Type	Diesel
	Model	D-330
	Related hp	100
	No. of cylinders	4
	Displacement (cu in.)	350
Transmission	Type	Power shift
	No. speeds forward	4
	No. speeds reverse	4
	Max. speed forward (mph)	4.8
	Max. speed reverse (mph)	6.2
Shipping Wt. (lb)		25,380
Liquid Capacity (gal)	Fuel tank	60
	Cooling system	10
	Crank case	5.75

Source: Construction Methods, November 1968

Table 8

DETAILED EQUIPMENT SPECIFICATIONS

INTERNATIONAL HARVESTER 175B
Front End Loader - Crawler

Bucket	Heaped Capacity (cu yd)	2
	Struck Capacity (cu yd)	1.72
	Width (in.)	86
	Type	4-in-1
Overall Dimensions (in.)	Height	85
	Width	86
	Length (bucket on ground)	--
	Length (bucket in carry position)	188
	Track length on ground	87
	Width of track shoe	15
	Track gage	66
Engine	Type	Diesel
	Model	DT-407
	Rated hp	120
	No. of cylinders	6
	Displacement (cu in.)	407
Transmission	Type	Power shift, constant mesh
	No. speeds forward	4
	No. speeds reverse	4
	Max. speed forward (mph)	5.2
	Max. speed reverse (mph)	6.2
Shipping Wt. (lb)		27,765
Liquid Capacity (gal)	Fuel tank	60
	Cooling system	10
	Crank case	5.75

Source: Construction Methods, November 1968

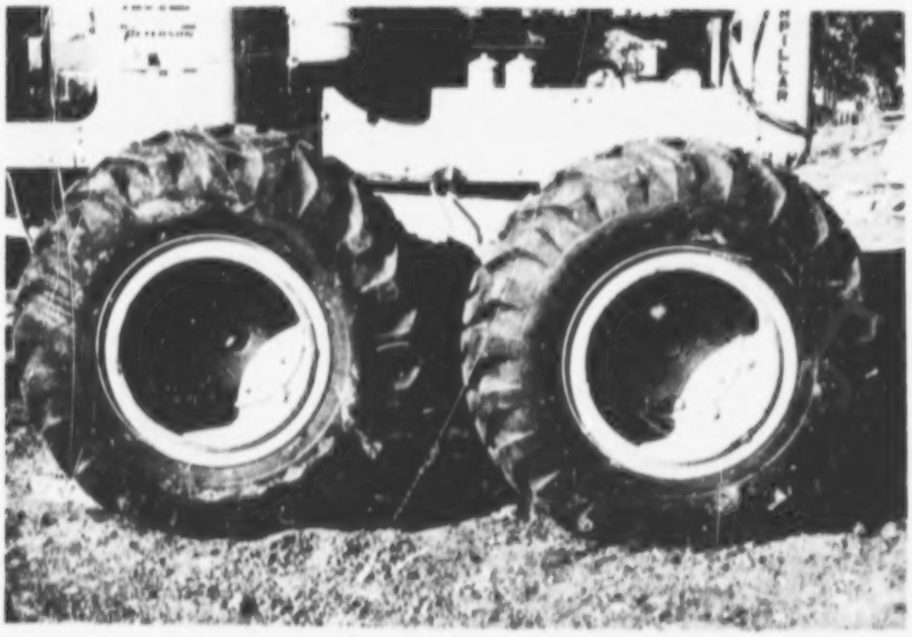


Fig. 16. Motorized Grader Equipped with Flotation Tires

area. The oil was spilled onto the surface by means of method (a) described previously (see page 17). Also, as indicated in Table 9, in several tests the test area was covered with straw or a test area was selected that was covered with kelp and other debris.

Table 9

BEACH TEST CONDITIONS

EQUIPMENT EVALUATED	TIDAL ZONE AREA				BACKSHORE AREA	
	Without Oil	With Oil	With Straw	With Kelp	Without Oil	With Oil
Motorized Grader	x	x	x	x	x	
Motorized Elevating Scraper	x	x	x	x	x	
Motorized Scraper	x				x	
Front End Loader	x	x			x	x
Motorized Grader with Motorized Elevating Scraper	x	x	x	x	x	
Motorized Grader with Front End Loader	x					

Figures 17 and 18 show the Tunitas Beach test area covered with straw before and after operations with the motorized elevator scraper. No difficulty was experienced in removing the straw or when windrowing the straw with a motorized grader. The straw serves as a binder and assists in reducing spillage when making a thin cut.

The beach-restoration procedures evaluated for each piece of equipment and combination of equipment in the Phase I tests are listed in Table 10. The basic test procedure was to operate the equipment on a 100- by 30-ft test area and to time and photograph the operations and obtain appropriate measurements, including width of cut, depth of cut, size of windrows and visual observations of effectiveness (i.e., amount of spillage). Each piece of candidate equipment was tested individually to determine its operating characteristics and performance in removing a thin surface layer of sand under various beach conditions. The motorized grader was then operated in combination with the elevator scraper and the front end loader to determine the effectiveness of combined operations.

During both the individual tests and the combined equipment tests, the various pieces of heavy equipment were operated at different speeds, depths of cut, and blade angles to determine the optimum operating characteristics for equipment performance on a sandy beach. Finally, several tests were run to determine cycle time (i.e., a complete loading cycle, which includes loading, hauling, dumping, and return to loading position). In some of these tests, longer test areas were used to approximate actual conditions (e.g., the scraper will normally operate in one direction and continue loading until its capacity is reached instead of making short, 100-ft passes). The major observations concerning the testing are given in Appendix D.

One measure of efficiency is the amount of sand removed during a beach-restoration operation. For each operation, the volume of sand (in cubic yards) removed per acre of beach cleaned was calculated from the data listed in Appendix D. The results, given in Table 11, show that the smallest amount of material per acre was removed with the motorized grader and motorized elevating scraper working in combination (Restoration Procedure A, Table 10). The motorized elevating scraper operating alone was the next best procedure. The most inefficient arrangement utilized a front end loader to scrape up and remove the material.

The range of values given is based on several tests. An important parameter in calculating the total volume removed is the depth of cut, and in each test an average depth of cut was measured. In some instances, due to the bearing surface of the test area and topography, it was difficult for the operator to maintain a constant depth of cut.

Another measure of efficiency is the rate (hr/acre) at which beach areas are cleared. Table 12 presents the rate of clearing for the various pieces of equipment evaluated and combinations of equipment. The calculations are based on these operations in which cycle times were taken.

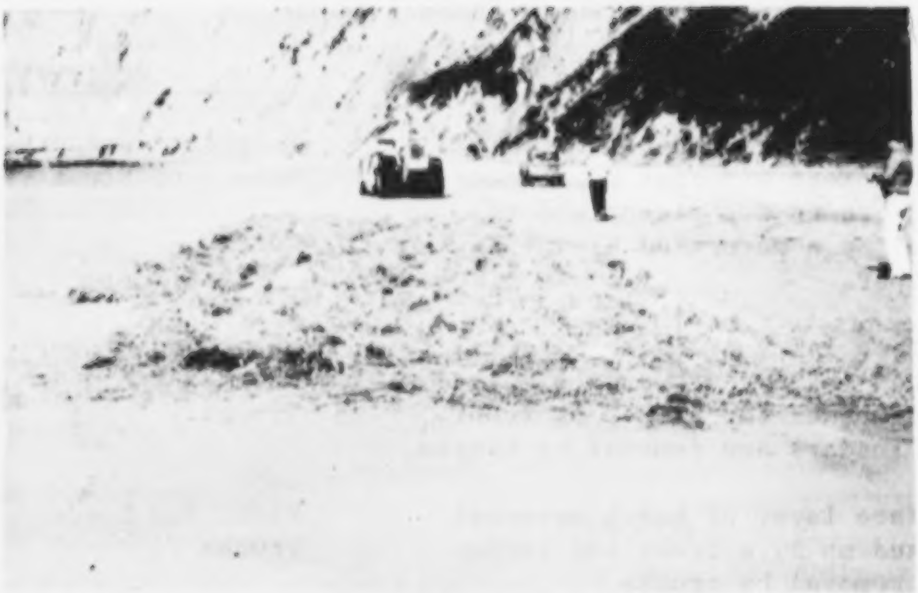


Fig. 17. Test Area Before Removal of Straw

Fig. 18. Test Area After Straw Removal by Motorized Elevator Scraper

Table 10

BEACH RESTORATION PROCEDURES
EVALUATED IN PHASE I TESTS

PROCEDURES	EQUIPMENT
A. Surface layer of beach material pushed into windrows by a motorized grader for pickup and removal by a motorized elevating scraper.	Motorized Grader Motorized Elevating Scraper
B. Surface layer of beach material pushed into windrows by a motorized grader for pickup by front end loaders and removal by trucks.	Motorized Grader Front End Loader Trucks
C. Surface layer of beach material picked up by a front end loader and removal by trucks.	Front End Loader Trucks
D. Surface layer of beach material scraped up for removal by a motorized elevating scraper.	Motorized Elevating Scraper

The values given for each equipment item and/or combination of items are based on equipment performing under optimum conditions (i.e., the motorized elevating scraper loading in first gear and hauling and returning from the dump area in second gear; the motorized grader operating in second gear for both forward and reverse; and the front end loader operating in first gear for scraping and second gear for hauling and dumping).

The calculated values are based on the haul distances given in Table 12 for each operation. Increasing or decreasing these distances would increase or decrease the rates accordingly. When a motorized grader is used in combination with a motorized elevating scraper or front end loader, the indicated rates may be increased by the use of additional scrapers or front end loaders. The motorized grader is capable of producing windrows continuously, and several motorized elevating scrapers or front end loaders can be utilized to pick up and remove the windrows.

Table 11

SAND REMOVAL DURING VARIOUS BEACH RESTORATION OPERATIONS

	VOLUME OF SAND REMOVED (Cu yd/acre of beach cleaned)		
	Loose Sand or Backshore Area	Firm Hard-Packed Beach	Firm Beach With Straw Applied @ 100 Bales/Acre
Motorized Grader and Motorized Elevating Scraper	130-145	70-100	180-200
Motorized Elevating Scraper	300-400	200-250	
Motorized Grader and Front End Loader		300-325	
Front End Loader	800-1200		

Table 12

ACRES CLEARED AND HAULED BY VARIOUS TYPES AND COMBINATIONS OF EQUIPMENT

	CLEARANCE RATES (hr/acre)	HAUL DISTANCE (ft) TO DUMP (one way)
Motorized Grader and Motorized Elevating Scraper	0.77-1.67	160-100
Motorized Elevating Scraper	0.95	100
Motorized Grader and Front End Loader	2.78	100

As indicated in Table 12, the motorized grader/motorized elevating scraper combination is the most efficient for an equivalent length of haul. The least efficient is the front end loader, working singly. An example of how production (hr/acre) decreases with increased haul distance (one-way) is shown in Fig. 19 for the motorized grader/motorized elevating scraper combination and the motorized elevating scraper working singly.

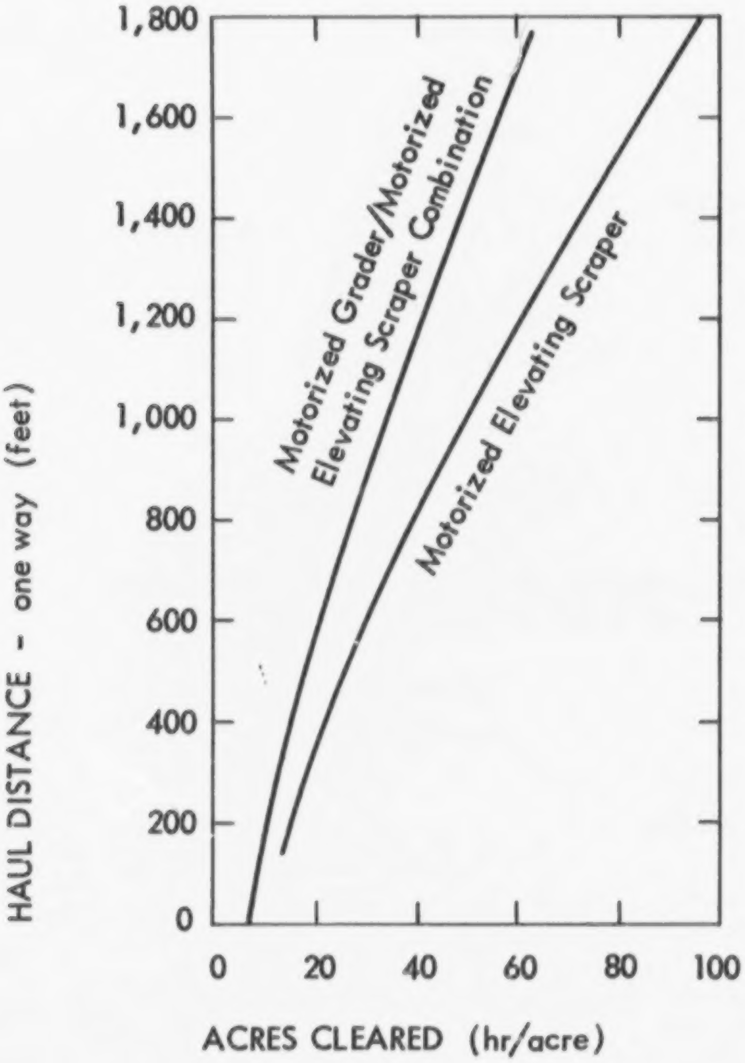


Fig. 19. Acres Cleared vs. Haul Distance by Motorgrader and Motorized Elevating Scraper Working Singly.

As indicated in Table 9, tests were also conducted on backshore test areas. On the Francis State Park Beach, where very loose dry sand was encountered, the rubber-tired equipment (motorized grader and motorized elevating scraper) could not operate efficiently and in several instances became immobilized. Only the crawler-mounted front end loader could perform. However, as indicated in Table 11, the use of a front end loader is very inefficient in terms of the volume of material removed.

Procedures for minimizing the oil contamination of backshore areas should be instituted at the first indication of a possible shoreline pollution event. Under normal tide conditions, a berm or dike at the high-tide mark can prevent oil from contaminating backshore areas. However, as in the case at Santa Barbara, heavy winter storms can wash oil onto these areas, including that beyond breakwaters.

CONVEYOR-SCREENING EVALUATION TESTS

Scaled mock-up tests were conducted to qualitatively evaluate a conveyor-screening system for its effectiveness in separating oil contaminated straw and sand from clean sand. The test apparatus used included the movable test bed and scaled motorized grader blade and scaled elevating scraper system described previously (Figs. 5 and 6) and a 3/8-in. mesh wire conveyor, 4-in. wide, with 1-in. flights every 12 in.

The test bed, on which an oil-straw mixture had been placed, was pulled under the test apparatus, where the scaled motorized grader blade (set at a 53-deg angle perpendicular to the direction of travel) cast a windrow in front of the scaled elevating scraper. The elevating scraper, operating at a speed of 130 rpm and a chain speed of 85 ft/min, picked up the windrow and deposited it into the conveyor-screening system. The conveyor-screening system, operating at 87 rpm and 68 ft/min, discharged the oil-straw-sand mixture into a hopper. The material, weighed before and after each test, showed that approximately 5% of the oil-soaked straw passed through the 3/8-in. mesh conveyor screen.

Transfer of oil from the oil-straw mixture to clean sand picked up in the process was apparent. This is due to the mixing action during formation of windrows. The quantity of clean sand contamined through this process can be minimized by proper operating procedures while removing the oil-contaminated material from beach areas.

A second series of tests was conducted in the same manner, except that a 1/8-in. wire mesh conveyor screen was utilized. In this instance, no straw passed through the screen. The conveyor-screening system was also effective in separating agglomerated pellets of oil-sand from clean sand.

SECTION V

PHASE II DEMONSTRATION TESTS

Full-scale demonstration tests were conducted to evaluate the restoration procedures and equipment modifications selected in the Phase I evaluation tests. Performance criteria measured for each procedure/equipment evaluated included:

(a) Efficiency with which each procedure/equipment item collected or spilled oil-contaminated material.

(b) The ratio of oil to inert material in the mixture collected.

(c) The cost per unit of oil collected and unit of beach material handled.

(d) Capability of the equipment to operate under a variety of beach conditions.

(e) Performance characteristics at various speeds, blade angles, and depths of cut.

A description of the experimental procedures and results obtained in the Phase II demonstration tests are described in the following paragraphs.

BEACH TEST SITES

The Phase II demonstration tests were conducted at Half Moon Bay Harbor and the Francis State Park Beach (see Fig. 8), both previously described in Section IV. The Francis State Park Beach, which exhibits very poor trafficability, was used to evaluate restoration procedures/equipment designed to operate on a low-bearing sand. The majority of the Phase II tests, however, were conducted on the Half Moon Bay Harbor beach.

Figures 20 and 21 are views of the Half Moon Bay Harbor beach at mid-tide. Figure 22 is a contour map of the beach areas shown in Figs. 20 and 21. Sand samples were taken at several locations at the high-tide level, low-tide level, and from the backshore, as indicated in Fig. 22. The grain size gradation was determined in the manner described in Section IV and the results are presented in Table 13 and plotted in Fig. 23.

The sand on the beach is poorly graded, varying from very coarse to very fine grain size, with the coarser sands lying at the low-tide line. In general, the beach is characterized by a medium-packed sand with medium to firm footing. The tidal zone slope averaged 3%, except for a portion of the east beach area, where at low tide the exposed beach had a slope of less than 1%.

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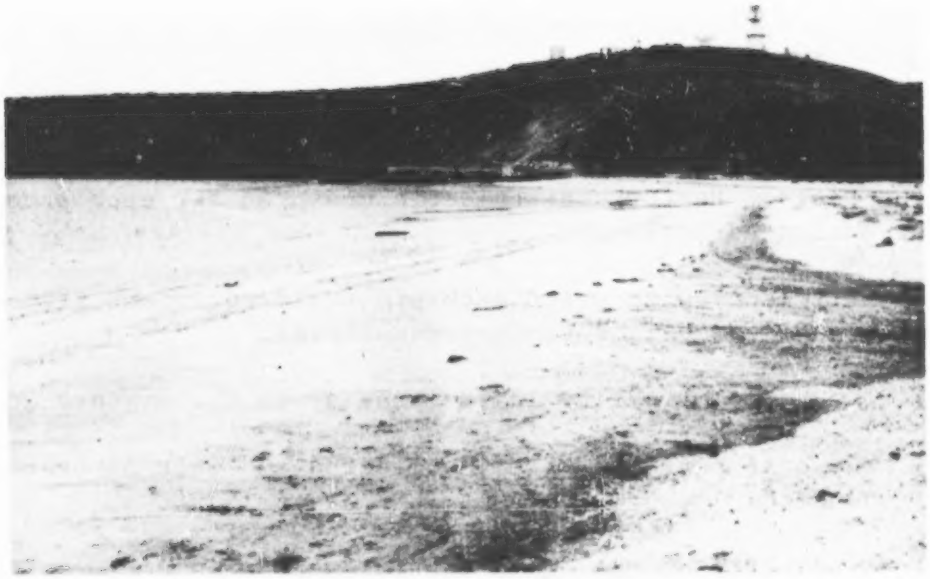

Fig. 20. Half Moon Bay Harbor Beach
View Looking East

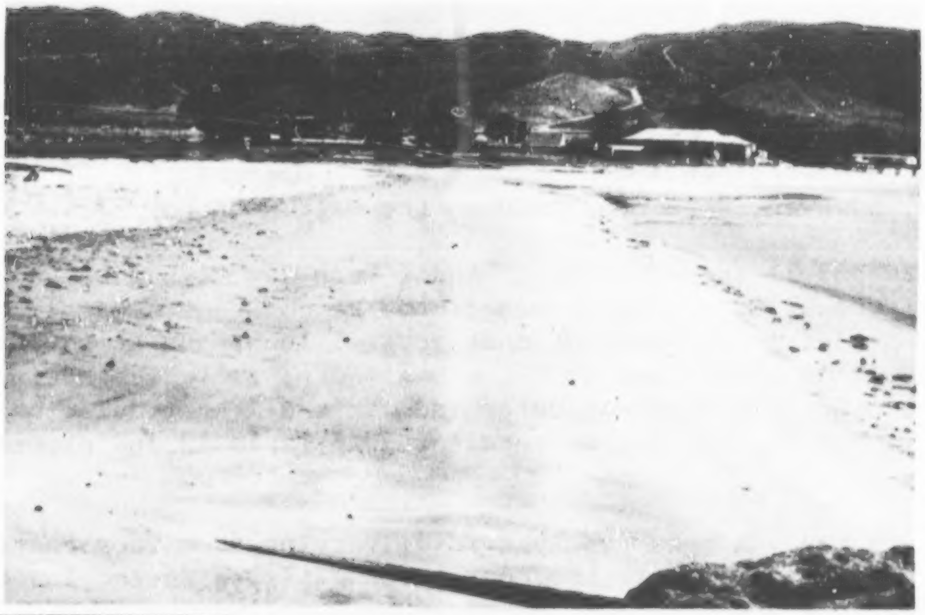

Fig. 21. Half Moon Bay Harbor Beach
View Looking West

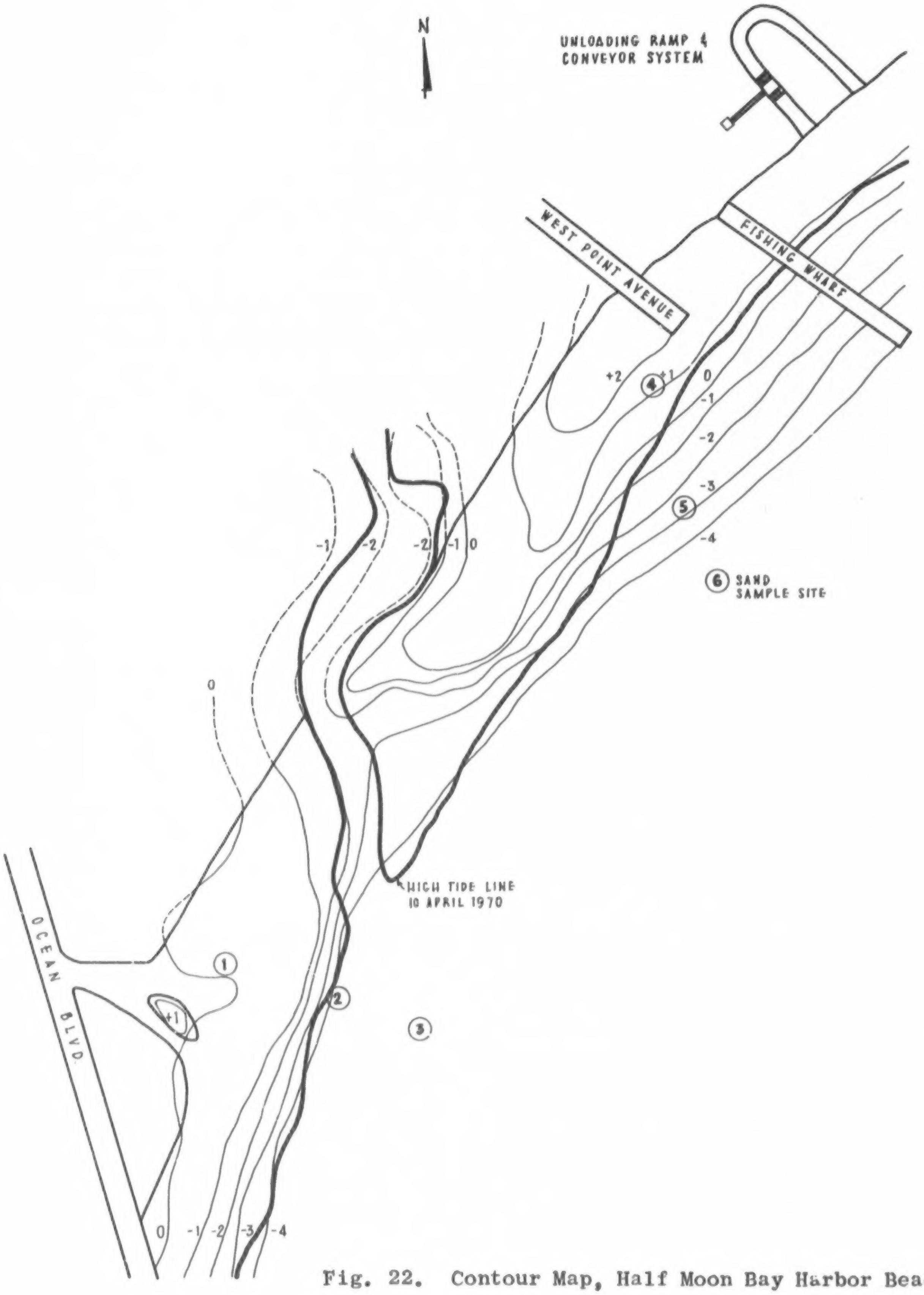
N
UNLOADING RAMP & CONVEYOR SYSTEM
WEST POINT AVENUE
FISHING WHARF
+2
④
+1
0
-1
-2
-3
⑤
-4
⑥ SAND SAMPLE SITE
-1
-2
-2
-1
0
0
HIGH TIDE LINE 10 APRIL 1970
OCEAN BLVD
①
+1
②
③
0
-1
-2
-3
-4

Fig. 22. Contour Map, Half Moon Bay Harbor Beach

Table 13

RESULTS OF MECHANICAL ANALYSIS - HALF MOON BAY HARBOR
(% of sample by weight)

LOCATION	MEDIAN SIZE (μ)	SIEVE SIZE (μ)					
		> 1168	> 701	> 495	> 351	> 147	< 147
1. West-Backshore	215	.1	.8	2.8	7.1	72.9	16.3
2. West-High Tide Line	195	.04	.03	.07	.75	82.12	16.99
3. West-Low Tide Line	860	34.05	23.79	5.56	3.44	24.92	8.24
4. East-Backshore	580	26.04	17.1	10.4	9.4	28.9	7.8
5. East-High Tide Line	265	24.1	5.4	2.5	3.3	47.7	17.0
6. East-Low Tide Line	840	31.1	29.9	23.7	4.7	4.7	5.9

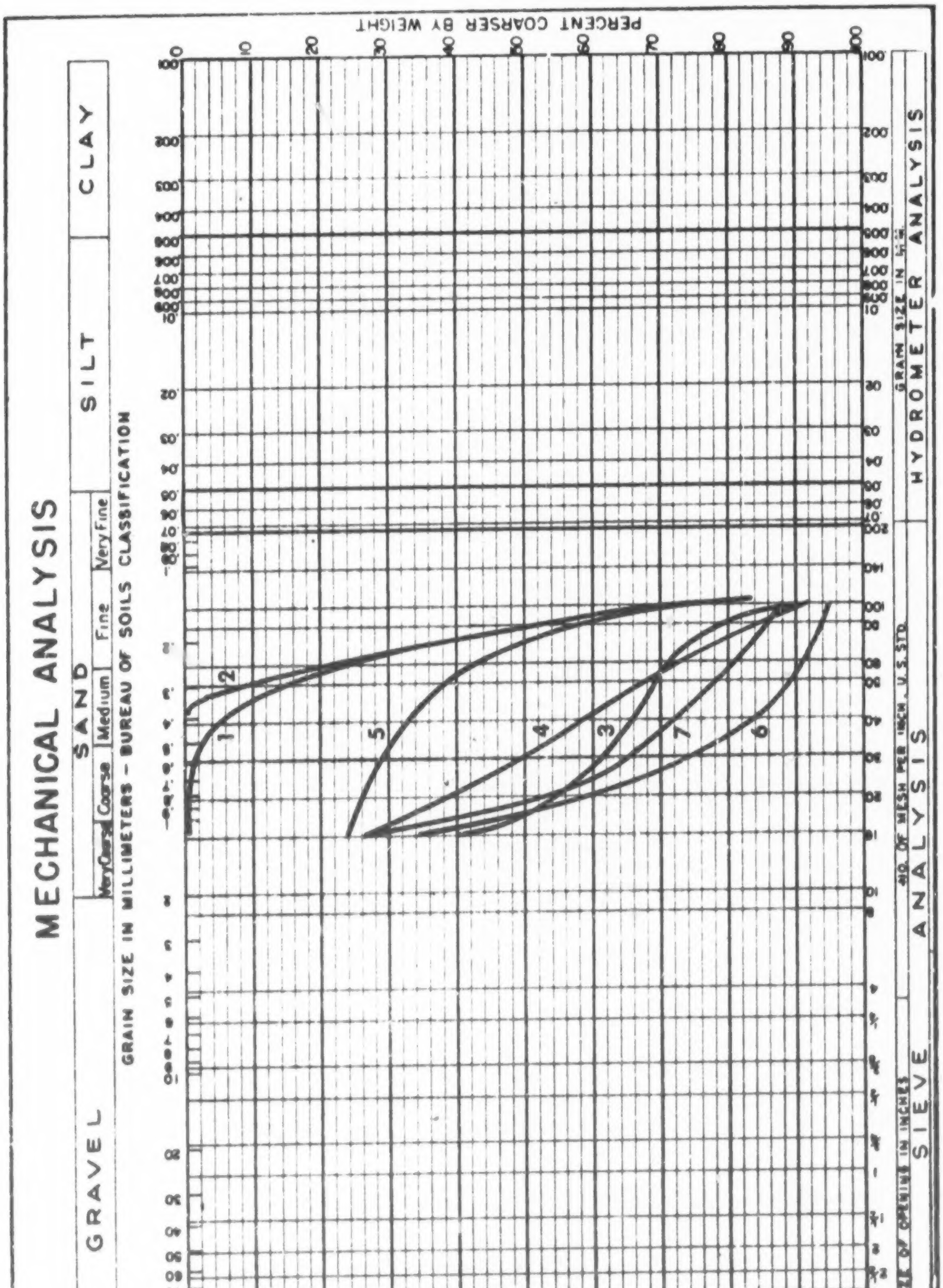

Fig. 23. Sand Classification for Half Moon Bay Harbor Beach Test Area

CONTAMINATION AGENT

Bellridge crude, a heavy asphaltic crude from the San Joaquin Valley, California, oil fields, was used in the Phase II demonstration tests as the contamination agent. The important characteristics of Bellridge crude are given in Table 14. The physical characteristics of Bellridge crude, i.e., viscosity and degrees API gravity, are similar to those of Bunker C fuel oils, which constitute a large percentage of oil transported by tankers along the U.S. coastline. The viscosity of Bellridge crude is also in the same range as the weathered Alaskan crude (see Table 3) that was utilized in the Phase I evaluation tests. The required quantity of Bellridge crude was purchased from the Standard Oil Company of California.

The contamination agent was dispersed onto the test area by means of a 200-gal skid-mounted tank, supporting a 16-ft spreader bar and pump (see Fig. 24). The dispersing system was towed with either a motorized grader or motorized elevating scraper. This dispersal method was selected over that used in the Phase I evaluation tests because (a) a larger oil loading could be applied onto the test area, and (b) the time required to contaminate a large test area was considerably shortened.

Figure 25 shows a test area after crude oil dispersal. As shown, a uniform film of oil resulted from this dispersal method. A close-up of the resultant oil film is shown in Fig. 26. The depth of penetration was limited to 1 in.; and in some tidal zone areas having a wet packed surface, penetration was limited to 1/4 to 1/2 in.

Oil-sand pellets to simulate tar lumps that are occasionally found on beaches were made by mixing weathered crude oil and sand and hand-forming pellets about 1-1/2 to 2 in. in diameter.

The pellets were hardened by weathering for 5 to 10 days. The weathered pellets were randomly distributed over the test area by hand. Figure 27 shows a test area on which the oil-sand pellets were distributed.

The quantity of crude oil distributed, weight of oil-sand pellets dispersed, and size of each test area contaminated were obtained for each test conducted to provide the initial oil-contamination level (gallons or pounds per square foot).

RESTORATION PROCEDURES EVALUATED

The beach-restoration procedures recommended for full-scale testing in the Phase II demonstration tests, based on the Phase I preliminary evaluation tests, include the use of: (a) motorized graders; (b) motorized elevating scrapers; (c) crawler tractor-drawn elevating scraper; (d) front end loaders; and (e) conveyor-screening systems. A summary of the restoration procedures evaluated are listed in Table 15. A total of

Table 14

GENERAL CHARACTERISTICS
BELLRIDGE CRUDE

Source: San Joaquin Valley

Color: Brownish Black

Specific Gravity: 0.966

Gravity: ^{o}ApI 15.9 at 60^{o}F

Pour Point: + 10^{o}F

Viscosity, Saybolt Furol at 122^{o}F: 87 Sec

Kinematic at 122^{o}F: 183.5 Sec

COMPONENTS	% OF SAMPLE
Total Gasoline and Naphtha	4.6
Kerosene Distillate	7.4
Gas Oil	17.0
Residium	71.0

Source: Chevron Research Co.

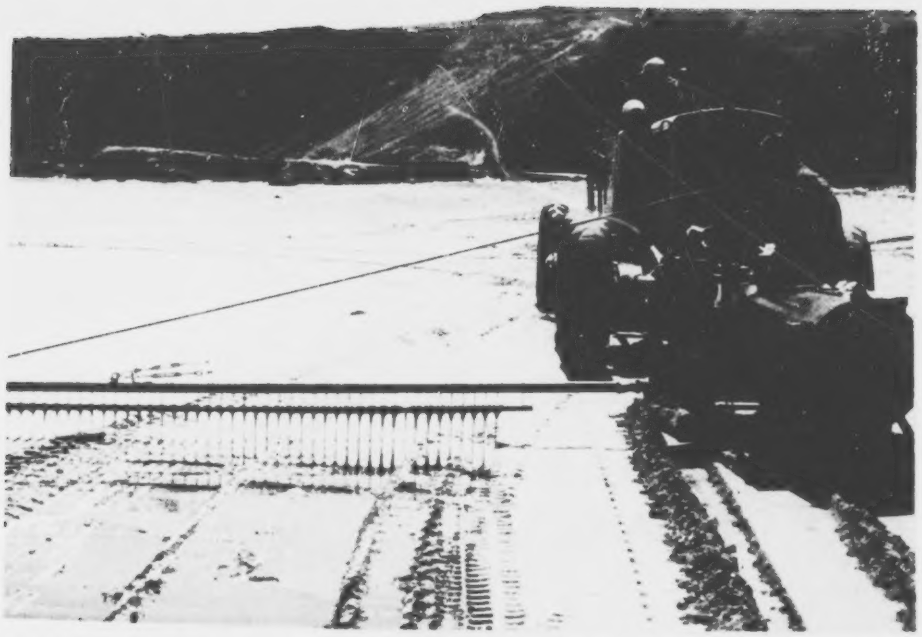

Fig. 24. Skid-Mounted Oil Distributor Spreading Oil on Test Area

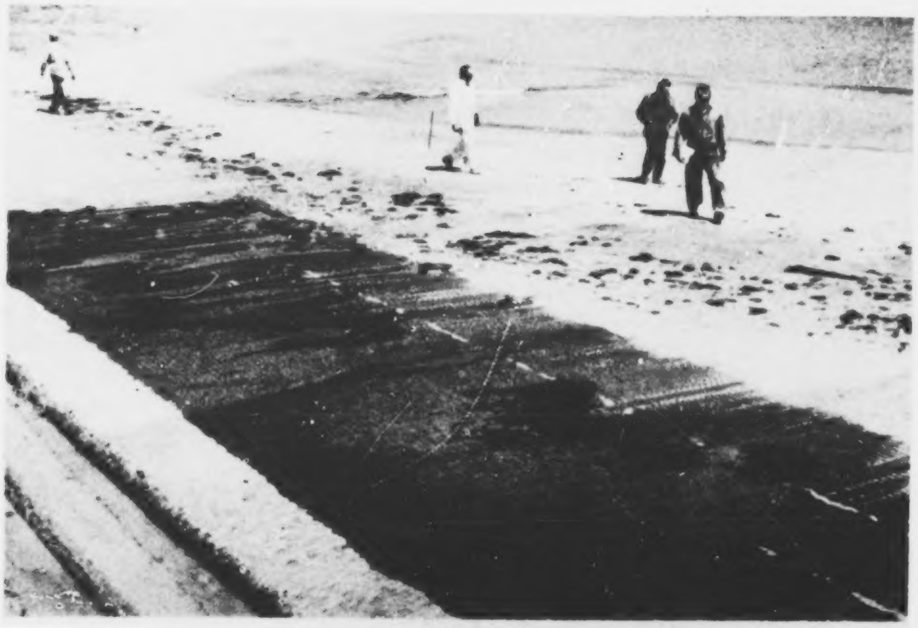

Fig. 25. Oil-Contaminated Test Area

20 tests were conducted on test areas exhibiting the listed beach conditions. The equipment items utilized included those evaluated previously in the Phase I tests (see Section IV, page 37) and the following additional equipment:

- Front End Loader - (Fig. 28)
  International Harvester, Model H-80,
  rubber tired, 3-cu-yd capacity, 225 hp.

- Portable Conveyor-Screening Plant (Fig. 29)
  Barber Greene, Model PS-70, 24-in. belt,
  270 tons/hr.

- Non-Self-Propelled Elevating Scraper (Fig. 30)
  Johnson Mfg. Co., Model 80-C
  rubber tired, 8-cu-yd capacity.

- Mulch Spreader (Fig. 31)
  Finn Mulch Spreader, Model P,
  10 tons/hr.

Detailed specifications for each of the equipment types evaluated in the Phase II demonstration tests are listed in Tables 5 through 8 and Tables 16 through 19. As indicated in Section IV, the choice of make and model of equipment evaluated was determined only by equipment availability at time of testing and were representative of their classes.

TEST CONDITIONS AND DATA COLLECTED

The restoration procedures were evaluated for five beach conditions:

(1) Tidal zone - contaminated with a thin film of oil.

(2) Tidal zone - contaminated with an oil-straw mixture.

(3) Tidal zone - contaminated with randomly dispersed, agglomerated oil-sand pellets.

(4) Backshore zone - contaminated with a thin film of oil.

(5) Backshore zone - contaminated with randomly dispersed, agglomerated oil-sand pellets.

The following measurements and data were collected for each test series conducted:

PRE-TEST CONDITIONS

(a) Quantity of contamination agent dispersed on test area.

(b) Total area contaminated.

(c) Average depth of penetration of oil.

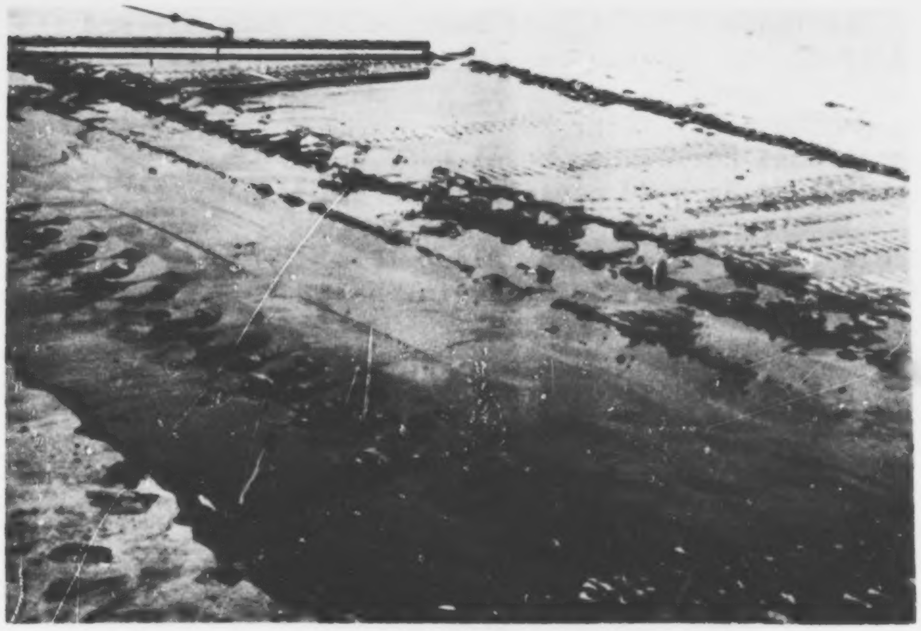

Fig. 26. Close-up of Oil Film on Test Area

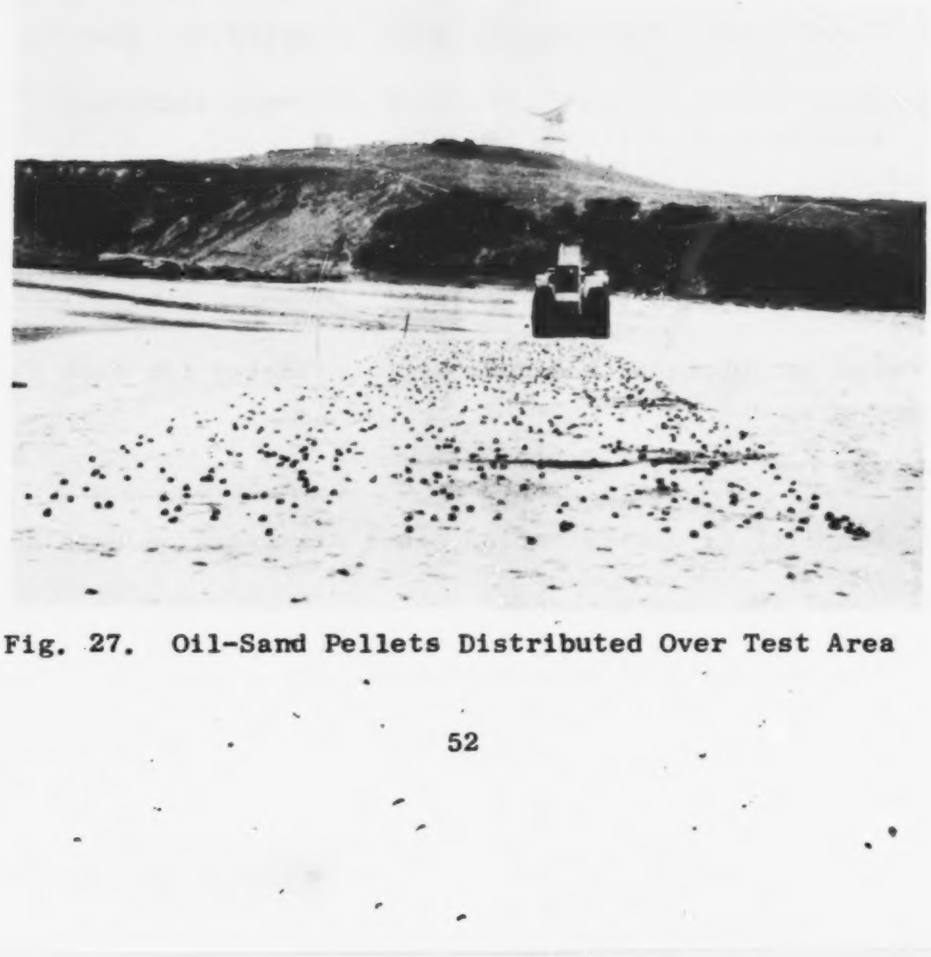

Fig. 27. Oil-Sand Pellets Distributed Over Test Area

Table 15

SUMMARY OF RESTORATION PROCEDURES EVALUATED

Test Series	Restoration Procedure	Equipment Modifications	Beach Condition				
			1 Tidal Zone With Thin Film of Oil	2 Tidal Zone With Thin Film of Oil Plus Straw	3 Tidal Zone With Oil-Sand Pellets	4 Backshore With Thin Film of Oil	5 Backshore With Oil-Sand Pellets
A.	Combination of motorized grader and motorized elevating scraper	None	A-1 A-1-1				
B.	Combination of motorized grader and motorized elevating scraper	Sand baffles in bowl of scraper	B-1(a)	B-2(a)			
C.	Combination of motorized grader and towed elevating scraper	Half tracks on motorized grader	C-1 C-1-1				
D.	Combination of motorized grader and front end loader mounted on rubber-tired tractor	None	D-1				
E.	Motorized elevating scraper	None	E-1	E-2(a)	E-3		
F.	Motorized elevating scraper	Sand baffles in bowl of scraper	F-1		F-3	F-4	F-5
G.	Combination of motorized grader and motorized elevating scraper	Sand baffles in bowl of scraper	G-1		G-3	G-4	G-5
H.	Combination of motorized grader and front end loader mounted on crawler tractor	None	H-1			H-4	

(a). Full-scale demonstration tests.

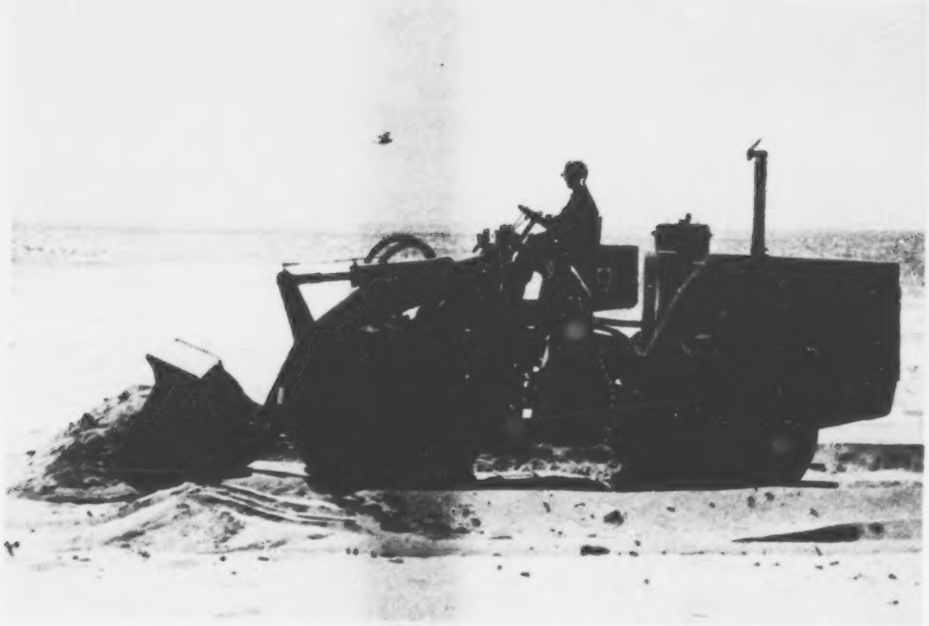

Fig. 28. Rubber-Tired Front End Loader

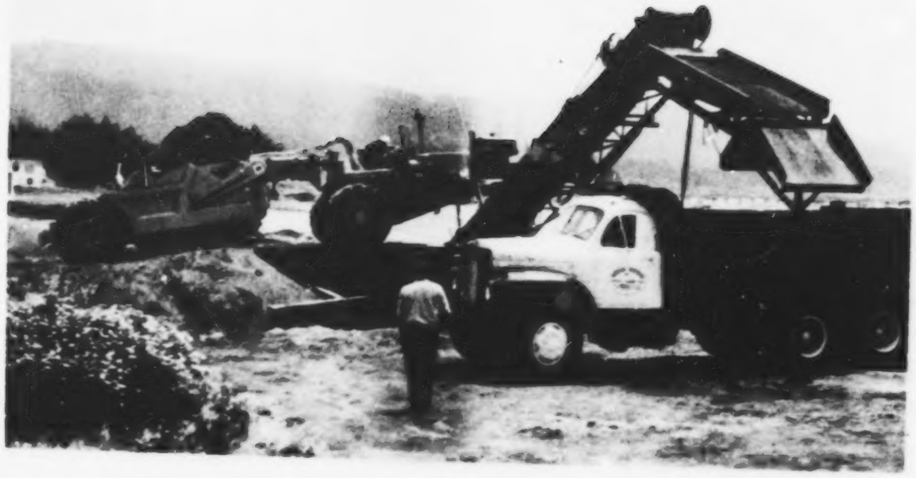

Fig. 29. Conveyor-Screening Plant

Fig. 30. Non-Self-Propelled Elevating Scraper

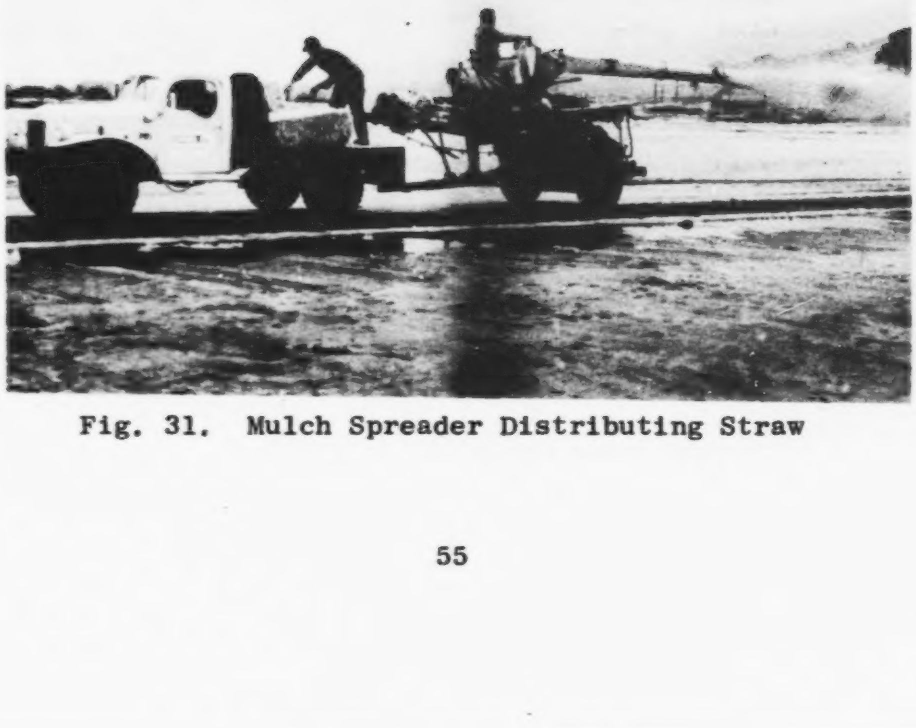

Fig. 31. Mulch Spreader Distributing Straw

Table 16

DETAILED EQUIPMENT SPECIFICATIONS
INTERNATIONAL HARVESTER H-80

Bucket	Heaped Capacity (cu yd)	3
	Struck Capacity (cu yd)	2.5
	Width (in.)	110
	Type	General Purpose
Overall Dimensions (in.)		
	Height	134
	Width	106
	Length (bucket on ground)	285
	Length (bucket in carry position)	281
	Wheel	117
	Tire Size	23.5 x 25
Engine	Type	Diesel
	Model	DT-429
	Rated HP	225
	No. of cylinders	6
	Displacement (cu in.)	429
Transmission	Type	Power Shift Constant Mesh
	No. speeds forward	3
	No. speeds reverse	3
	Max. speed forward (mph)	23.7
	Max. speed reverse (mph)	28.4
Operating wt (lb)		31,900
Liquid Capacity (gal)		
	Fuel Tank	80
	Cooling System	9-1/2
	Crank Case	5-3/4

Table 17

DETAILED EQUIPMENT SPECIFICATIONS
BARBER GREENE MODEL PS-70
Portable Conveyor Screen

Belt Width (in.)	24	
Conveyor Length c/c (ft)		
Capacity (tons per hour)	270	
Weight including screen and trap (lbs)	14,500	
Engine type	Gasoline	
Model	Wisconsin-V6-40	
Rated HP	32	
No. of cylinders	4	
Screen		
Type	Single deck	
Length (ft)	10	
Width (in.)	42	
Mesh size and	3/8"	64"
Capacity (Tph)	3/4"	96"
	2"	170

Table 18

DETAILED EQUIPMENT SPECIFICATIONS
JOHNSON MODEL - 80C
Self-Elevating Scraper
Non-Self-Propelled

Power Required (minimum)	70 HP
Controls	Hydraulic
Hydraulic Pump Capacity Required	10-15 GPM
Capacity	8 cu yds
Dimensions (overall):	
Length (including tongue)	24'
(not including tongue)	19' 2"
Width	8'
Height (to top of bowl)	58"
(to top of elevator)	92"
Wheelbase	16' 2"
Width of Cut	90"
Minimum Turning Radius	12'
Axles:	
Front (2)	Stub Type
Rear (2)	Through Type
Bearings	Tapered Roller
Ground Clearance	15"
Gauge:	
Front (center to center of tires)	52"
Rear (center to center of tires)	64"
Tires (used airplane) (new tires optional)	1550-20
Elevator	
Gear Box	Worn Gear Type
Shipping Weight (approx.)	9,910

Table 19

DETAILED EQUIPMENT SPECIFICATIONS
FINN MULCHER MODEL P
(straw blower)

Capacity	10 ton/hr of straw
Engine	110 hp 4-cycle, air-cooled
Trailer Mounted	2-wheel axle
Power Feed	Chain driven
Discharge Spout	260 deg. rotation horizontally 75 deg. vertical movement

EQUIPMENT OPERATIONS

(a) Equipment conditions - blade angle, operating speed, depth of cut, elevator speed

(b) Size of windrows - length, width, depth

(c) Elapsed time for each pass

(d) Elapsed time for each loading cycle

(e) Volume of material in scraper bowl

(f) Elapsed time for each loading cycle

(g) Elapsed time for each unloading cycle

(h) Distance to unloading area

(i) Total cycle time

(j) Estimated amount of spillage

POST-TEST CONDITIONS

(a) Location and amount of contamination agent remaining on test area (see Appendix E for laboratory procedure for oil recovery from sand samples)

(b) Location and amount of debris, kelp, etc. remaining on test area

Table 20
DATA SUMMARY
REMOVAL OF THIN FILM OF OIL

TEST NO.	BEACH CONDITION[(a)]	EQUIPMENT EVALUATED	OIL CONTAMINATION		AREA CLEANED (sq yd)	CUT			TIME		VOLUME REMOVED (cu yd)	DISTANCE TO UNLOADING AREA (ft)	COMMENTS
			DISPERSED (gal)	AREA COVERED (sq ft)		WIDTH (ft)	DEPTH (in.)	LENGTH (ft)	OPERATION (min,sec)	CYCLE (min,sec)			
A-1	1	Motorized Grader Motorized Elevating Scraper	43.5	808	450	27	2-3	150	3 29,30	32,30	45	750	Inexperienced motorized grader operator, could not maintain a constant depth of cut. Required four passes to clean area and resultant windrow difficult to pick up with motorized elevating scraper. Excessive spillage required additional cleanup passes.
A-1-1	1	Motorized Grader Motorized Elevating Scraper	50.5	800	300	27	2-3	100	2,15 13,30	15,30	36	750	Test A-1 rerun with experienced operator, area cleaned with only three passes with a minimum of spillage.
C-1	$1^{(b)}$	Towed Elevating Scraper Crawler Tractor	None	None	376	8.75	1-1.5	387	4,45	4,45	17	---	Towed elevating scraper operated with no difficulty in low-bearing sand.
C-1-1	$1^{(b)}$	Motorized Grader with half-tracks	None	None	---	---	---	---	---	---	---	---	Motorized grader with half-tracks able to operate on low-bearing sand however due to low shear strength of sand, unable to form windrows.
D-1	1	Motorized Grader Front End Loader Rubber tired	50.5	545	287	25.2	1.5	100	2,40 10,55	13,35	14	350	Excessive spillage around each edge of bucket of front end loader
E-1	1	Motorized Elevating Scraper	46	930	211	19	2.5-3.5	100	11,45	11,45	26	550	
F-1	1	Motorized Elevating Scraper with sand baffles	41.5	450	111	20	2.5	50	7,22	7,22	7	2450	Tires of motorized elevating scraper picks up oil; however oil mixes with sand, forming oil-sand pellets and are easily picked up in successive passes.
F-4	4	Motorized Elevating Scraper with sand baffles	59.5	705	120	21.5	4	50	13,51	13,51	11	1700	
G-1	1	Motorized Grader Motorized Elevating Scraper with sand baffles	45.5	672	230	21	.75-1.5	100	5,5 13	18,5	16	1900	Inexperienced motorized grader operator, required five passes to clean area, forming a large windrow that was difficult to remove by the motorized elevating scraper, thus causing excessive spillage.
G-4	4	Motorized Grader Motorized Elevating Scraper with sand baffles	33	510	221	20	1.5-2	100	3,15 ---	---	18	800	Motorized grader experienced some traction difficulty on backshore area.
H-1	1	Motorized Grader Front End Loader Crawler Tractor	54.5	637	322	29	.75-1	100	2,47 12,10	14,57	12	90	Excessive spillage from bucket on front end loader.
H-4	4	Motorized Grader Front End Loader Crawler Tractor	49	468	180	27	1.5-2	60	2,20 6	8,20	9	50	Excessive spillage from bucket on front end loader.

(a) See Table 15
(b) Conducted on Francis State Park Beach

Table 21

DATA SUMMARY
(Full Scale Demonstration Tests)

TEST NO.	BEACH CONDITION	EQUIPMENT EVALUATED	OIL CONTAMINATION		AREA CLEANED (sq yd)	CUT			TIME (min, sec)		VOLUME REMOVED (cu yd)	DISTANCE TO UNLOADING AREA (ft)	COMMENTS
			DISPERSED (gal)	AREA COVERED (sq ft)		WIDTH (ft)	DEPTH (in.)	LENGTH (ft)	OPERATION	CYCLE			
B-1	1	Motorized Grader Motorized Elevating Scraper with sand baffles Conveyor-Screening System	152.5	3200	735	22	1-1.5	300	2,17 25,10	27,27	44.5	600	Area cleaned in two passes with motorized grader. Resultant windrow easily picked up by motorized elevating scraper.
B-2	2	Motorized Grader Motorized Elevating Scraper with sand baffles Straw Blower Conveyor-Screening System	201.5	3040	860	35	1.5-2	220	5,30 36,30	42	61	700	Straw dispersed over oil after test area contaminated. Conveyor-screening system separates 75%-80% of straw picked up from sand.
E-2	2	Motorized Elevating Scraper Straw Blower Conveyor-Screening System	190	2920	445	20	1-1.5	200	26,30	26,30	34	1000	Very little spillage occurred. Straw on test area eliminates pickup of oil on tires.

Table 22

DATA SUMMARY
(Removal of Oil-Sand Pellets)

TEST NO.	BEACH CONDITION	EQUIPMENT EVALUATED	OIL CONTAMINATION		AREA CLEANED (sq yd)	CUT			TIME (min,sec)		VOLUME REMOVED (cu yd)	DISTANCE TO UNLOADING AREA (ft)	COMMENTS
			DISPERSED (gal)	AREA COVERED (sq ft)		WIDTH (ft)	DEPTH (in.)	LENGTH (ft)	OPERATION	CYCLE			
E-3	3	Motorized Elevating Scraper Conveyor-Screening System	190	2400	267	20	1-1.5	120	23,15	23,15	13.5	800	Slight spillage in side windrows formed by scraper bowl. Conveyor-screening system very efficient in separating oil-sand pellets from clean sand.
F-3	3	Motorized Elevating Scraper with sand baffles Conveyor-Screening System	160	909	167	20	1-1.5	75	2,41	2,41	8	250	
F-5	5	Motorized Elevating Scraper with sand baffles Conveyor-Screening System	100	600	98	17.6	2	50	7,31	7,31	7	1750	
G-3	3	Motorized Grader Motorized Elevating Scraper with sand baffles Conveyor-Screening System	160	731	167	20	1-1.5	75	2,27 4,45	7,12	9	750	Utilizing motorized grader eliminates spillage noted in Test E-3.
G-5	5	Motorized Grader Motorized Elevating Scraper with sand baffles Conveyor-Screening System	200	650	221	20	1	100	1,31 3,25	4,56	3.5	800	

Still photographs and motion pictures will be taken before, during, and after each test series to document each operation.

TEST RESULTS

The major observations and data collected during the Phase II testing are given in Tables 20 through 22. Included are detailed data on each test, including quantity of oil contamination; time of operation, area cleaned; depth, width, and length of cut; material removed; and comments on the performance of the equipment. The principal test variables during the Phase II testing were beach conditions, equipment modifications, and equipment combinations. Specific equipment variables, such as blade angle and operating speeds, were evaluated during the Phase I testing, and the optimum settings determined therein were utilized in the Phase II test program. The depth of cut was dependent upon the depth of oil penetration in each test.

Measures of effectiveness for each restoration procedure in terms of the total volume of sand removed per acre of beach cleaned, the cleaning rate, the ratio of oil removed to the volume of sand removed, and the residual amount of oil remaining on each test area after cleaning are presented in Tables 23 through 25. The total area cleaned in each test was usually greater than the area contaminated with oil. Thus, to allow for comparisons between restoration procedures, the total cleared area was assumed to be uniformly contaminated with oil at the initial oil loadings given in Tables 23 through 25. The initial oil loadings utilized would approximate 10,000 gal of oil deposited over 1 mile of beach, 30 ft wide.

The interaction between the oil loadings and the various equipment types evaluated was minimal, i.e., the presence of the film of oil on the beach surface did not affect the ability of the equipment to pick up, cut, or transport the contaminated beach material. The mixing action that occurred in the cutting and/or pickup of a thin film of oil and the underlying clean sand results in a uniform oil-sand mixture. Under these conditions, it is not possible, by screening techniques, to separate oil-contaminated sand from clean sand.

The experience of the equipment operator to properly operate earthmoving equipment under the beach conditions encountered in the Phase II tests was found to have an important influence on the volume of material removed from each test area. The motorized grader operator for Test A-1, A-1-1, G-1, and G-4, which were conducted in combination with the motorized elevating scraper, experienced difficulty in maintaining a constant depth of cut, and in most instances cut deeper than required, thus forming large windrows. This resulted in removal of an excessive amount of material from the test area.

In contrast, the experienced motorized grader operator utilized during Tests D-1 and H-1, conducted in combination with front end loaders, maintained a constant 1/2- to 1-in. cut, thereby forming smaller windrows and minimizing the volume of material removed.

NOT REPRODUCIBLE

Table 23

SUMMARY OF TEST RESULTS
(Removal of Thin Film of Oil)

TEST NO.	BEACH CONDITION	RESTORATION PROCEDURE	MODIFICATIONS	VOLUME OF SAND REMOVED (cu yd/acre)	RATE[a] (hr/acre)	INITIAL OIL LOADING (gal/sq yd)	OIL REMOVED (gal/cu yd)	OIL RESIDUAL (gal/sq yd)
A-1	1	Combination of Motorized Grader and Motorized Elevating Scraper	None	483	3.85	0.48	4.8	0.0013
A-1-1	1	Combination of Motorized Grader and Motorized Elevating Scraper	None	580	2.70	0.57	4.7	---
C-1	1	Towed Elevating Scraper	None	228	7.14	----	---	---
D-1	1	Combination of Motorized Grader and Front End Loader mounted on rubber tired tractor	None	235	5.55	0.83	17.1	0.0006
E-1	1	Motorized Elevating Scraper	None	596	4.00	0.45	3.6	0.0002
F-1	1	Motorized Elevating Scraper	Sand Baffles	305	1.10	0.83	13.1	---
F-4	4	Motorized Elevating Scraper	Sand Baffles	443	2.70	0.76	8.2	0.001
G-1	1	Combination of Motorized Grader and Motorized Elevating Scraper	Sand Baffles	336	1.64	0.62	8.8	0.0001
G-4	4	Combination of Motorized Grader and Motorized Elevating Scraper	Sand Baffles	394	---	0.58	7.2	0.0009
H-1	1	Combination of Motorized Grader and Front End Loader mounted on crawler tractor	4-1 Bucket	180	21.0	0.77	21.8	0.002
H-4	4	Combination of Motorized Grader and Front End Loader mounted on crawler tractor	4-1- Bucket	236	37.0	0.94	19.3	0.0019

(a) Based on 500-ft distance to unloading area.

Table 24

SUMMARY OF TEST RESULTS
(Full Scale Demonstration Tests)

TEST NO.	BEACH CONDITION	RESTORATION PROCEDURE	MODIFICATIONS	VOLUME OF SAND REMOVED (cu yd/acre)	RATE[a] (hr/acre)	INITIAL OIL LOADING (gal/sq yd)	OIL REMOVED (gal/cu yd)	OIL RESIDUAL (gal/sq yd)
B-1	1	Combination of Motorized Grader and Motorized Elevating Scraper	Sand Baffles	297	2.56	0.43	7.05	0.0002
B-2	2	Combination of Motorized Grader and Motorized Elevating Scraper with straw added	Sand Baffles	343	2.78	0.60	8.4	---
E-2	2	Motorized Elevating Scraper with straw added	None	377	2.44	0.58	7.6	---

---

(a) Based on 500-ft distance to unloading area.

Table 25

SUMMARY OF TEST RESULTS
(Removal of Oil-Sand Pellets)

TEST NO.	BEACH CONDITION	RESTORATION PROCEDURE	MODIFICATIONS	VOLUME OF SAND REMOVED (cu yd/acre)	RATE[a] (hr/acre)	INITIAL OIL PELLET LOADING (lb/sq yd)	OIL PELLETS REMOVED (lb/cu yd)	OIL PELLET RESIDUAL (lb/sq yd)[b]
G-3	3	Combination of Motorized Grader and Motorized Elevating Scraper	Sand Baffles	260	2.32	2.0	36.5	0
G-5	5	Combination of Motorized Grader and Motorized Elevating Scraper	Sand Baffles	76	1.64	2.8	175	0
F-3	3	Motorized Elevating Scraper	Sand Baffles	231	---	1.6	33	0.045
F-5	5	Motorized Elevating Scraper	Sand Baffles	345	1.75	1.5	21.1	0.009
E-3	3	Motorized Elevating Scraper	None	245	4.35	0.7	14.1	0.015

(a) Based on 1500-ft distance to unloading area.

(b) A value of 0 indicates no oil-sand pellets remained on test area.

The average depth of oil penetration on most of the tests was limited to 1/2 to 1 in. However, varying oil penetration was noted to some extent on most test areas. Its extent depended upon the nature of the beach test area and the length of the interval between loading and removal. Oil penetration greater than 1 in. usually occurred in small areas (2 to 3 sq ft) where coarser sand had concentrated. Removal of these lenses of oil necessitated, in some instances, additional cleanup passes; however, they could have been easily removed manually.

In Test E-2, the test area was a hard-packed tidal flat, and oil remained pooled on the surface, with little to no penetration. In Test B-2, in an area in the upper tidal zone, oil remained on the test area 2 to 3 hours prior to removal, and during this time, oil penetrated 2 to 3 in., thus requiring additional cleanup passes.

REMOVAL EFFECTIVENESS

The oil removal effectiveness was determined by manually removing all of the visible oil remaining on the test area subsequent to the completion of a restoration procedure and stripping the oil from the oil-sand mixture as described in Appendix D. The residual amount of oil for each test is given in Tables 23 through 25. The oil removal effectiveness was greater than 98% for all restoration procedures. The highest effectiveness was achieved through the use of the motorized grader and motorized elevating scraper working in combination. The lowest effectiveness was obtained with the tracked front end loader.

The removal effectiveness for oil-sand pellets was also greater than 98%. The residual oil-sand pellets on Tests F-3, F-5, and E-3 resulted from spillage following raising of the filled bowl on the motorized elevating scraper at the end of the test area.

CLEANING RATE

Table 26 presents cleaning rates for each restoration procedure evaluated on both tidal zone areas and backshore areas. The rates presented for the motorized grader and motorized elevating scraper were obtained from the full-scale demonstration tests, where the times of operation were longer, thus more realistic than the operating times from the small-scale tests. A major factor affecting the cleaning rate is the distance the material picked up has to be hauled to an unloading area. During the Phase II tests, distance to unloading areas varied from 50 to 2450 ft. To allow comparisons of cleaning rates, the rate data given in Tables 20 through 22 were normalized to a 500-ft, one-way hauling distance for all tests.

As indicated in Table 26, there was no significant difference in cleaning rates between the motorized elevating scraper working singly or in combination with the motorized grader. This is in contrast to the results of Phase I, where the motorized elevating scraper was slower when working singly. This disparity was due to the manner in which the motorized grader was operated. In Phase I, in which no oil was used, the motorized grader made 1/2-in. cuts, thus forming windrows that were easily picked up by the motorized elevating scraper. In Phase II, the motorized grader maintained a depth of cut at depth of oil penetration, which in most instances was 1 to 1-1/2 in., thus forming larger windrows which increased the loading time for the motorized elevating scraper.

Table 26

SUMMARY OF CLEANING RATES[(a)]

	TIDAL ZONE (hr/acre)	BACKSHORE ZONE (hr/acre)
Combination of Motorized Grader[(b)] and Motorized Elevating Scraper	2.6-2.8	--
Motorized Elevating Scraper	2.4	2.7
Combination of Motorized Grader and Front End Loader mounted on crawler tractor	21	37
Combination of Motorized Grader and Front End Loader mounted on rubber-tired tractor	5.4	--

---

(a) For 500 ft distance to unloading area.

(b) Motorized Grader operated at rate of 0.25 to 0.50 hr/acre.

Under oil contamination conditions where oil penetration is greater than 1-in., it is recommended that the motorized elevating scraper be used singly. In instances where oil penetration is limited to 1/2 in., such as on a firmly packed tidal flat, the use of a motorized grader and motorized elevating scraper working in combination is recommended.

The cleaning rates for front end loaders working in combination with a motorized grader were greater than those of the motorized grader-motorized elevating scraper combination by a factor of 8 for a crawler tractor mounted front end loader and a factor of 2 for the rubber-tired-mounted front end loader.

The rubber-tired-mounted front end loader experienced no traction difficulties on the Half Moon Bay Harbor beach test site, and also performed satisfactorily on the Francis State Park Beach, where other rubber-tired equipment experienced trafficability problems.

EQUIPMENT MODIFICATIONS

The analysis of the preliminary evaluation tests conducted in Phase I indicated that certain modifications to equipment and operating procedures should improve their performance in removing a thin layer of oil-contaminated sand from beach areas. These modifications in equipment and operating procedures were evaluated during the Phase II testing and included:

- Installation of sand baffle plates in the bowl of a motorized elevating scraper.
- Installation of steel half-tracks on a motorized grader.
- Use of towed elevating scraper on low-bearing sand beach areas.

SAND BAFFLE PLATES

When utilizing the motorized elevating scraper for removing windrows or making a thin cut, spillage occurs in the gap between the edge of the elevator flights and the side of the bowl. In normal earth-moving operations, this is considered slight and is ignored; however, in beach-restoration operations this spillage would prove unacceptable. In cooperation with the International Harvester Co., a sand baffle system was designed to fit in the bowl of the motorized elevating scraper. These baffle plates attach to each side of the bowl behind the elevator flights. The design and position of the baffle plates relative to the scraper bowl are shown in Fig. 32. As indicated, the plates are designed to close the 12-1/2-in. gap between the end of the elevator flights and the inside of the scraper bowl. The baffle system was prefabricated and field-installed. The design can be adapted to fit elevator hoppers of other makes and models. Figure 33 shows a sand baffle mounted in the bowl of the motorized elevating scraper.

The cost of prefabrication and installation of these baffle plates is approximately $300.

The effectiveness of the sand baffle plates in reducing spillage was evaluated by performing tests with and without the baffle plates installed. Test results given in Table 23 for Tests E-1 and F-1, and Tests A-1 and G-1 show that under the same beach condition, the addition of the baffle plates resulted in the removal of a significantly smaller amount of material. This was due to a reduction in spillage around the edges of the bowl, which eliminated the need for additional cleanup passes--passes which would be certain to gather additional extraneous sand. However, when straw was utilized as an oil absorbent, there was no significant difference in the pickup efficiency of the baffle-equipped motorized elevating scraper and the conventional unit.

STEEL HALF-TRACKS

The major problem in the use of the motorized grader was its inability to maintain traction when operating on a beach of low-bearing sand.

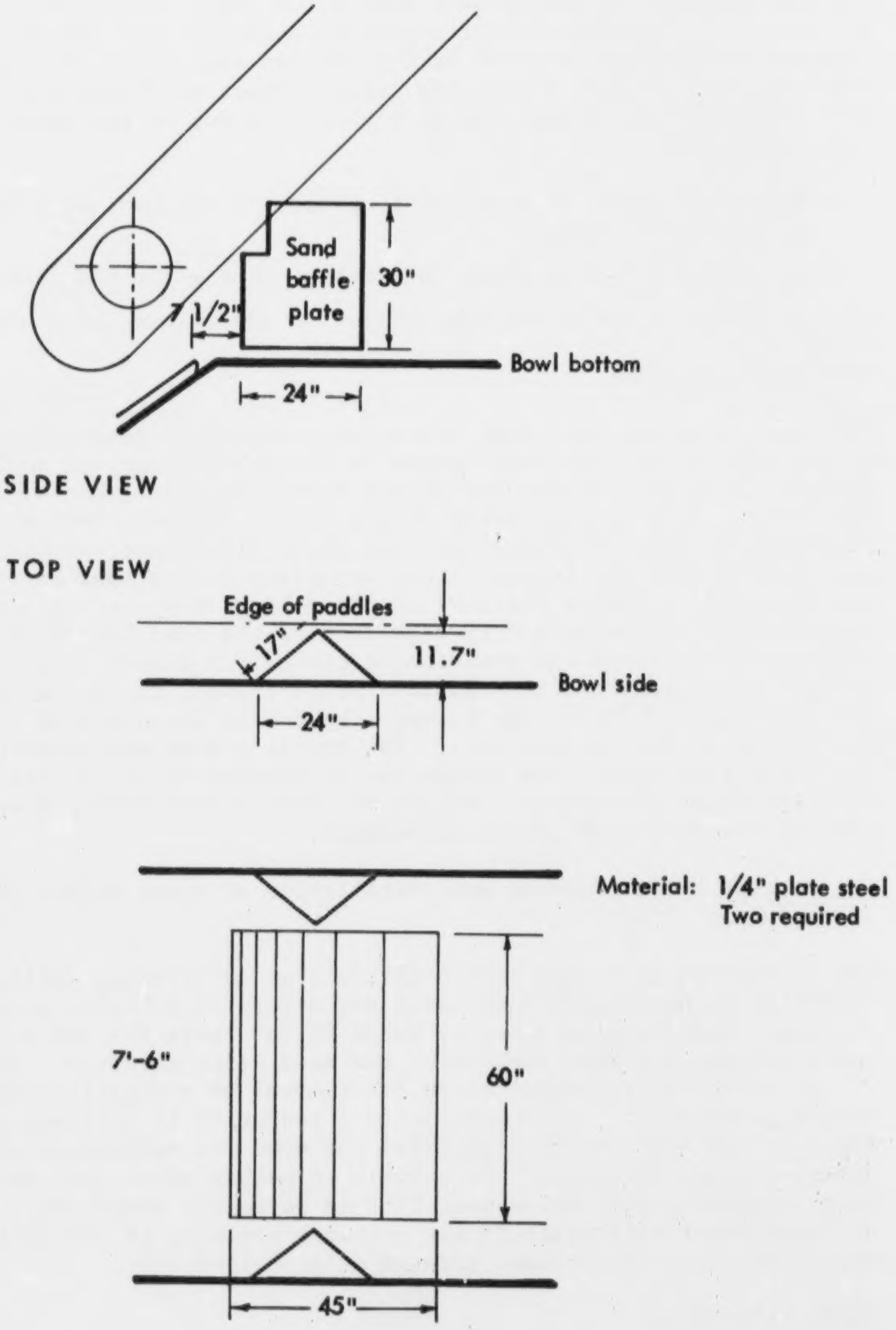
Sand baffle plate
30"
1/2"
24"
Bowl bottom
SIDE VIEW
TOP VIEW
Edge of paddles
17"
11.7"
Bowl side
24"
Material: 1/4" plate steel
Two required
7'-6"
60"
45"

Fig. 32. Design and Position of Baffle Plates

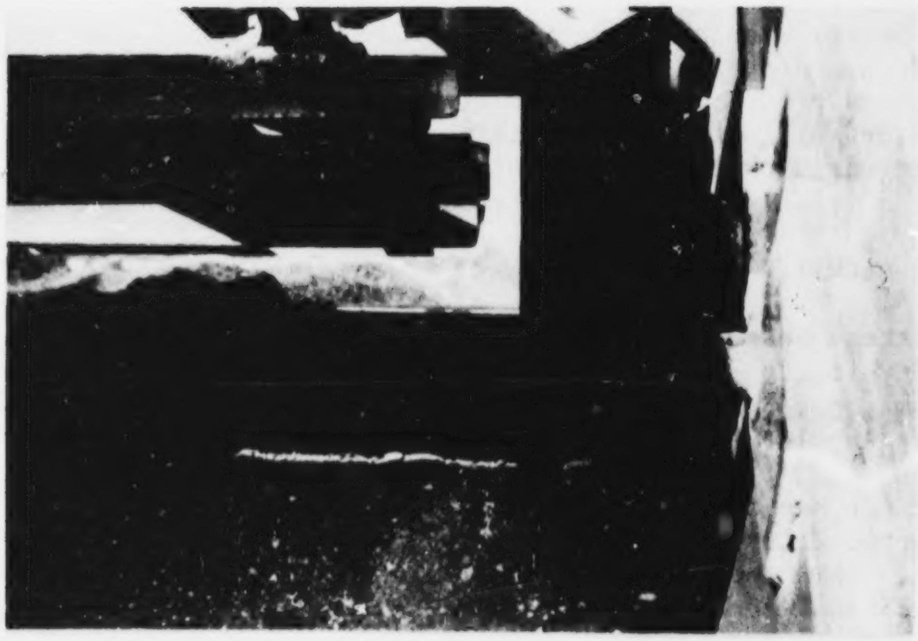

Fig. 33. Sand Baffle Mounted in Bowl of Motorized Elevating Scraper

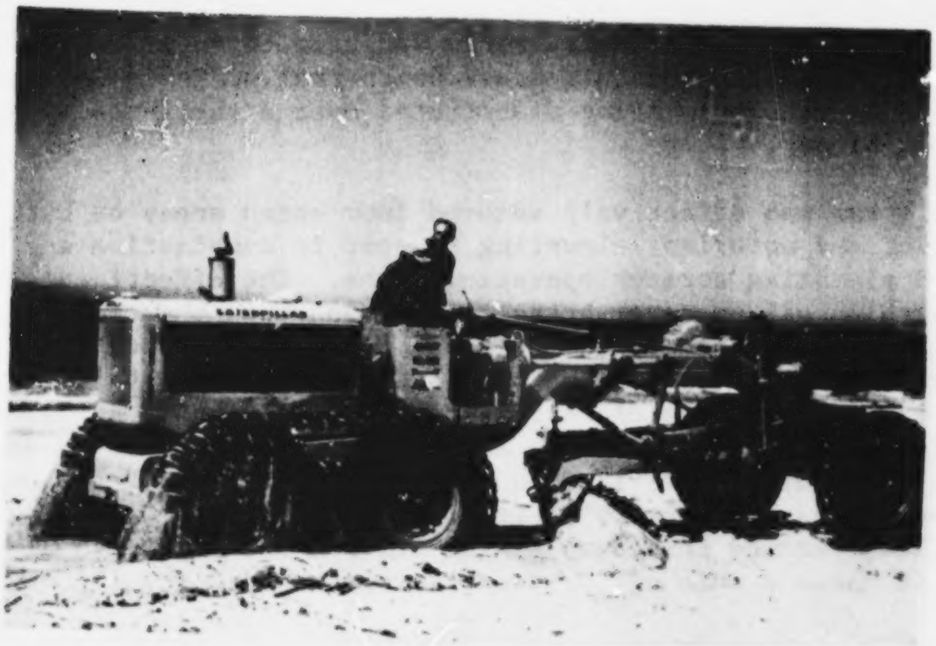

Fig. 34. Steel Half-Tracks Mounted on Motorized Grader

Flotation tires on all wheels will overcome this problem on most beaches; however, a motorized grader equipped with flotation tires became immobilized on Francis State Park Beach. A set of steel half-tracks were mounted on the motorized grader (see Fig. 34) and evaluated on Francis State Park Beach. The addition of the steel half-tracks enabled the motorized grader to maintain traction but the low-shearing strength of the sand prevented proper formation of windrows. The sand would roll under the blade or spill around the leading edge of the blade. Under such beach conditions, a tracked front end loader or towed elevating scraper would have to be utilized for the removal of oil-contaminated material.

TOWED ELEVATING SCRAPER

On certain beaches of low-bearing strength, the motorized elevating scraper in its present configuration became immobilized. Under these circumstances, a non-self-propelled elevating scraper, pulled by a tracked bulldozer should be used.

A Johnson Model 80-C (Fig. 30), non-self-propelled elevating scraper connected to a crawler tractor, was evaluated on the Francis State Park Beach. This combination proved very effective in making thin cuts both in the tidal zone and backshore areas. The use of tracked vehicles on oil contaminated beaches, however, will result in a great amount of spillage from oil sticking to the tracks.

STRAW REMOVAL

Straw has been the most widely used material for absorbing oil on both water and beach areas. However, the subsequent removal of straw from beach areas has involved the use of large amounts of manual labor. During the Phase II tests, straw was used to cover the film of oil dispersed during the full-scale demonstration Tests B-2 and E-2. Figure 35 shows the straw being distributed over a test area by means of a straw blower.

The straw was effectively removed from beach areas by both the motorized grader and motorized elevating scraper in combination and by the motorized elevating scraper operating alone. The effectiveness of straw in absorbing oil on beach areas will depend upon the time of initial contact with the oil. If the oil has time to penetrate into the beach surface, straw will not be beneficial. However, if straw is applied very soon after the oil arrives or on oil lying in pools, it is most effective in decreasing the amount of oil that would be picked up by the tires of rubber-tired equipment. Additionally, as noted in the Phase I tests, straw tends to act as a binder for sand and reduces spillage around the edges of the bowl on the motorized elevating scraper as it makes a thin cut or picks up windrows.

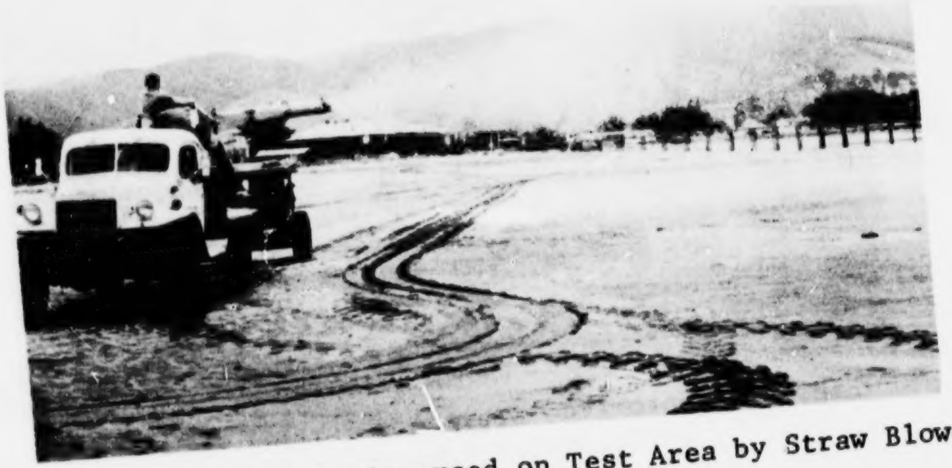

Fig. 35. Straw Being Dispersed on Test Area by Straw Blower

UNLOADING RAMP AND CONVEYOR SYSTEM

The use of an unloading ramp-conveyor system for transfer of oil-contaminated material to trucks for disposal was evaluated in Phase II. A ramp was constructed using surplus railroad ties for the main structural support and a track roadway over the conveyor bin. Figure 36 shows the motorized elevating scraper positioned on the ramp prior to unloading. The structural framework and roadway are so designed that they can be easily relocated. Only earth ramps at the new location would have to be constructed.

The conveyor system installed was used to load oil-contaminated sand directly into trucks (see Fig. 37) and, with a screening system attached, (see Fig. 38) to separate oil-contaminated debris from the sand.

A single-deck vibrating screen was used. The screen size was determined by type of material to be separated. For the separation of oil-contaminated straw or beach debris from the sand, a 2-in. mesh screen was used at the upper end of the screen deck and a 3/4-in. mesh at the lower end. This combination of screen sizes was found to efficiently separate all beach debris (kelp, seaweed, rocks, etc.) from the sand and 70 to 80% of the oil-straw mixture. When using the screening system to separate oil-sand pellets from clean sand, the 3/4-in. screen was used at the upper end of the screen deck and a 3/8-in. screen at the lower end. This combination successfully separated all the oil-sand pellets from clean sand.

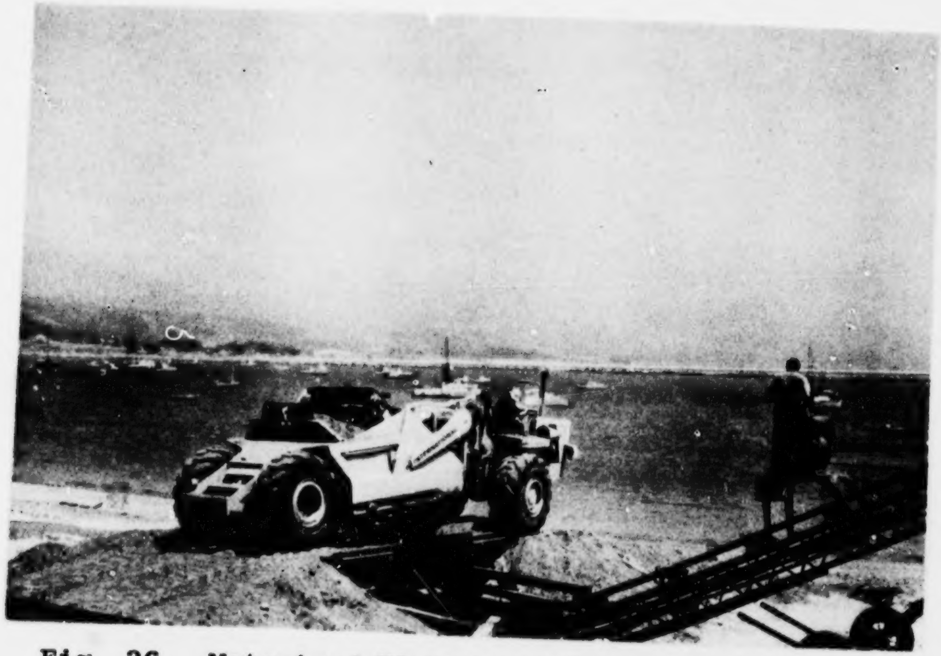

Fig. 36. Motorized Elevating Scraper Positioned on Unloading Ramp Prior to Unloading

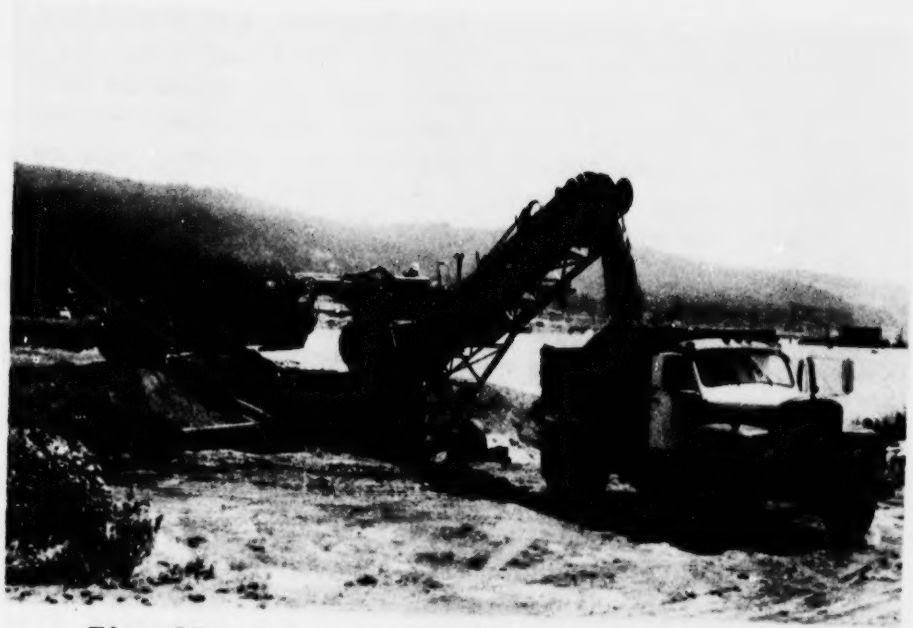

Fig. 37. Conveyor System Discharging Oil-Contaminated Sand Into Truck

The screening deck includes adjustable oversize and concentrating chutes to direct the flow of oversize and screened material (see Fig. 38).

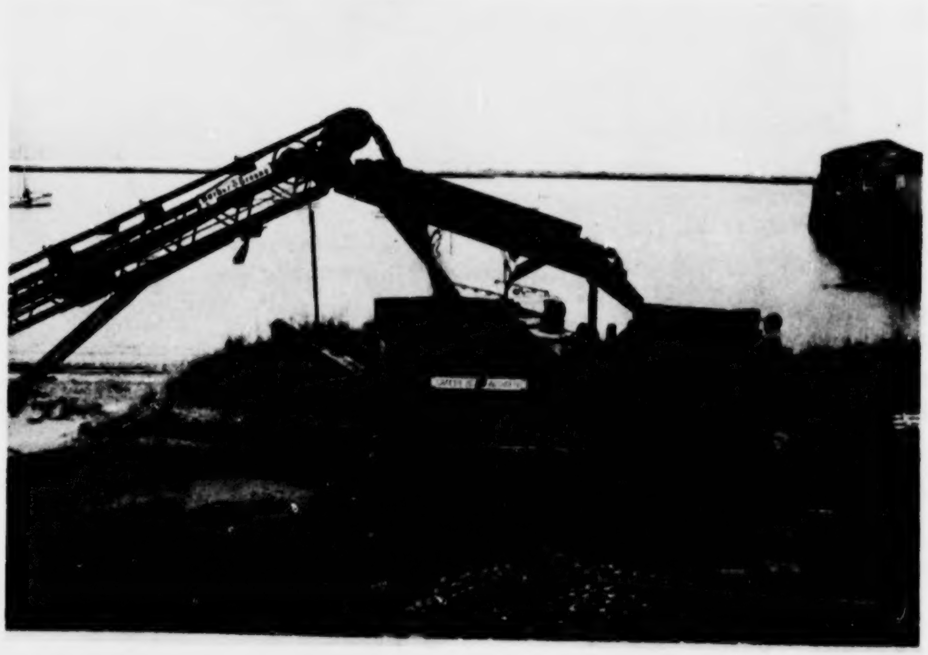

Fig. 38. Conveyor-Screening System Separating Oil-Straw Mixture From Clean Sand

Figure 39 shows a truck loaded with screened sand, and Fig. 40 shows the oversize beach debris that was directed into a second truck.

TRAFFICABILITY ANALYSIS

The use of heavy construction equipment in beach-restoration operations requires, quite obviously, that the equipment be able to operate on the beach without becoming immobilized. From the point of view of contingency planning for beach-restoration operations, it would be most beneficial to be able to make predictions regarding equipment mobility for a given beach. Therefore, a literature search was performed on the state of the art of trafficability analysis for off-the-road vehicles.

The results of the literature search indicated that there are two methods used in trafficability analysis of soils: the Vicksburg method[14] and the Bekker method.[15] The Vicksburg method, which was developed by the United States Army Corps of Engineers' Waterways Experiment Station (WES) in Vicksburg, Mississippi, is an empirical method designed to fit the requirements of the Corps of Engineers. The Bekker method was developed by the Army Material Command and is a theoretical method mainly used for the development of new vehicles.

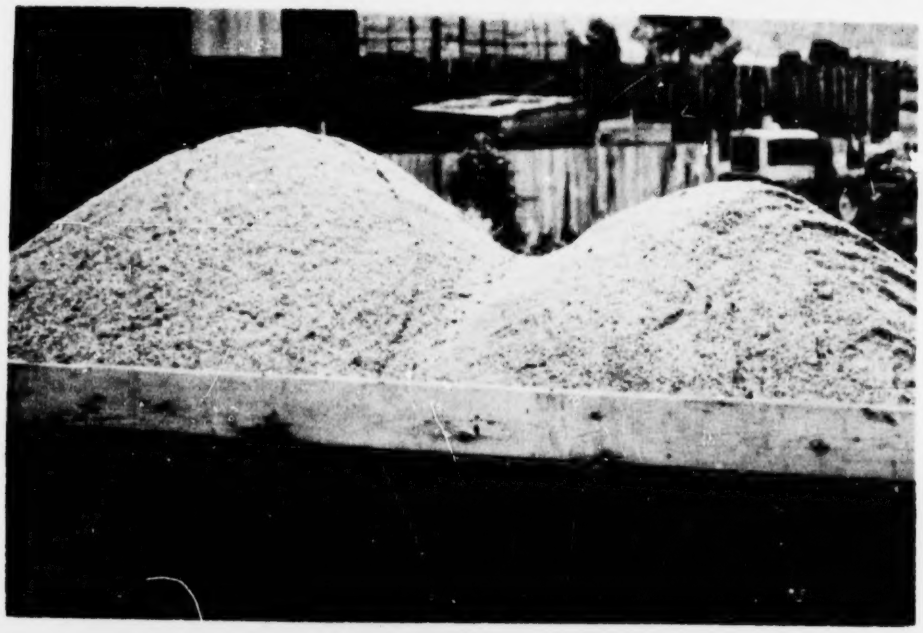

Fig. 39. Truck Load of Screened Sand

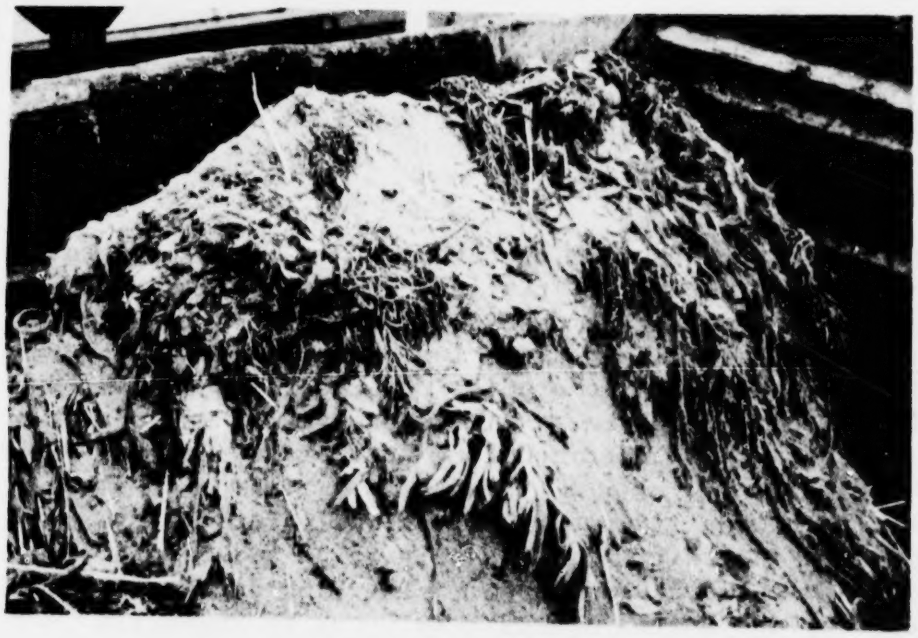

Fig. 40. Truck Load of Oversize Beach Debris Separated from Beach Sand

The Bekker method requires the determination of seven variables by means of fairly expensive and sophisticated testing equipment before the performance ability of a vehicle can be determined. The Vicksburg method, on the other hand, employs a single value, called the cone index value, determined by use of a cone pentrometer (see Fig. 41). The Vicksburg testing method appeared to be the more attractive of the two because of its simplicity, and it was used for this test program to determine trafficability factors on the beach test areas utilized.

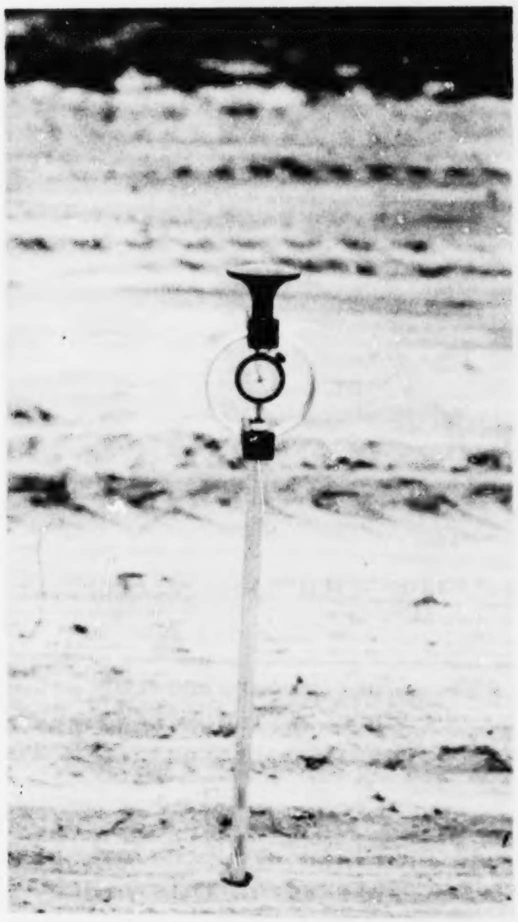

Fig. 41. Cone Pentrometer

A cone pentrometer is a field instrument consisting of a stainless steel cone mounted on a shaft in such a way that the cone can be forced into the soil surface by hand, as shown in Fig. 42. A proving ring and calibrated-dial assembly are used to measure the load applied. The penetration resistance is termed the "cone index" and is a measure of the shearing resistance of the soil.

The trafficability of a soil is dependent on the soil having adequate bearing capacity to support the vehicle and, at the same time, having sufficient traction capacity for the vehicle to develop the thrust necessary to overcome the rolling resistance. The ability of a soil to develop the required bearing and traction capacity is a function of the shearing resistance of the soil.

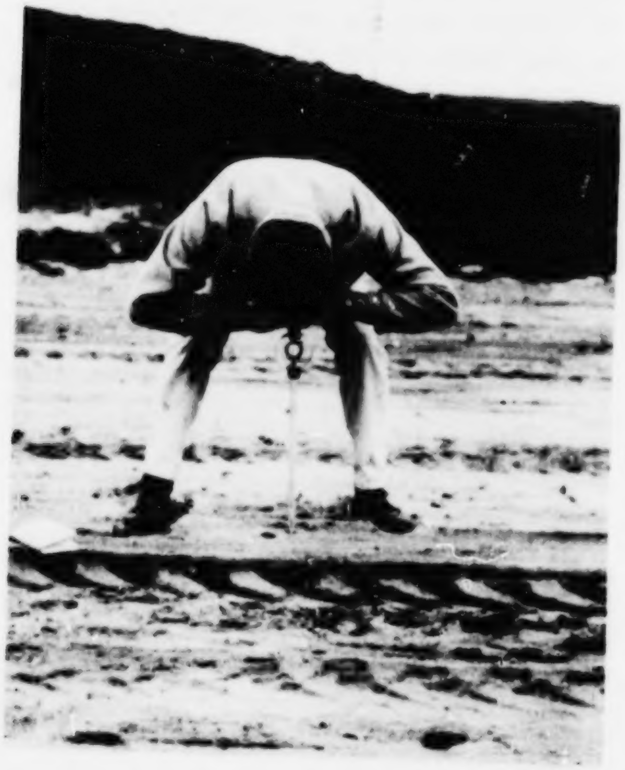

Fig. 42. Obtaining Cone Index Value with Cone Pentrometer

During the Phase II test program, a cone pentrometer, and the procedures described in Ref. 16, was utilized to obtain cone index readings on the beach test areas. The cone index values obtained, for a depth of 6 in., are given in Table 27.

The very low cone index values obtained on Francis State Park Beach are indicative of the poor trafficability encountered on this beach.

The Vickburg method[17] uses a series of calculations empirically derived from test programs performed by WES over a number of years in evaluating trafficability of various vehicle-terrain systems. The method has been proven[18] to be reliable in 78% of its predictions of "go," "no-go" values for trafficability of various earthmoving equipment on coarse grained soils (sand). The method can be used to calculate a minimum cone index value for a given piece of earthmoving equipment on the basis of certain equipment specifications (vehicle weight, tire size, etc.) and the tire pressure. This minimum cone index value represents the cone index below which the equipment will become immobilized.

Table 27

CONE INDEX VALUES

LOCATION	ZONE	CONE INDEX VALUE(a)
Half Moon Bay Harbor	Backshore	69
	Upper Tidal Zone	88
	Lower Tidal Zone	56
Francis State Park Beach	Backshore	17
	Tidal Zone	23

(a) Average of 10 readings at each location.

Minimum cone index values were computed (Table 28) for the motorized grader, motorized elevating scraper, and rubber-tired front end loader evaluated in this test program. Values were computed for the tire pressures of 20 psi and 40 psi. An example of the calculational procedure for determining the minimum cone index value for the rubber-tired front end loader is given in Table 29. Tire pressures of 40 ps or greater are those recommended for use under normal earthmoving operations. However, for operations in sand, lower tire pressures are required to prevent immobilization. During this test program, tire pressures were reduced to 20 psi on all equipment.

Table 28

MINIMUM CONE INDEX VALUES

EQUIPMENT TYPE	TIRE PRESSURE 20 Psi	TIRE PRESSURE 40 Psi
Rubber-Tired Front End Loader	11	33
Motorized Elevating Scraper	33	93
Motorized Grader	48	120

Table 29

EXAMPLE OF MINIMUM CONE INDEX VALUE CALCULATION

Vehicle H-80 Wheel-Mounted Front End Loader

Equation: Maximum towing force = 26.87 times strength factor plus 10.10 times contact area factor minus 1.52 times number of tires powered minus 0.61 times tire pressure minus 43.82

Vehicle and Soil Characteristics

(a) Gross vehicle wt, lb = 32,000
(b) Nominal tire width, in. = 23.5
(c) Rim diameter, in. = 25
(d) Number of tires powered = 4
(e) Tire ply rating = 12
(f) Tire pressure, psi = 20
(g) Minimum cone index of 0- to 6-in. layer = Y

Factors

(h) Wheel diameter factor = 2.0 × (b)* + (c)

$$= 2.0 \times 23.5 + 25 = 72$$

(i) Contact pressure factor $= 0.607 \times (f) + 1.35 \; \frac{117.0 \times (e)}{3.0 \times (b) + (h)} - 4.93$

$$= 0.607 \times 20 + 1.35 \left(\frac{117.0 \times 12}{3.0 \times 23.5 + 72} \right) - 4.93 = 20.5$$

(j) Contact area factor $= \text{Log} \left(\frac{(a)}{(i)} \right) = \text{Log} \left(\frac{32{,}000}{20.5} \right) = 3.1934$

(k) Strength factor = Log (g) = Log (Y)

$$\text{Maximum towing force} = 28.87 \times (k) + 10.10 \times (j) - 1.52 \times (d) - 0.61 \times (f) - 43.82 = 0$$

$$= 28.87 \times \text{Log } Y + 10.10 \times 3.1934 - 1.52 \times 4 - 0.61 \times 20 - 43.82$$

$$\text{Log } Y = \frac{29.85}{28.87} = 1.034; \; Y = 11 = \text{minimum cone index value}$$

---

* Letter in parentheses indicates value assigned to that factor number.

Comparison of the minimum cone index values tabulated in Table 36 and the cone index values measured on each beach test area shows that only the rubber-tired front end loader would be able to operate on all beach areas without becoming immobilized, whereas all the equipment evaluated could operate on the Half Moon Bay Harbor each. This prediction was substantiated during the test program.

This method of calculating equipment trafficability factors on a "go" or "no go" basis within 78% accuracy should be utilized in the preparation of contingency plans for beach areas susceptible to oil contamination. It must be noted, however, that due to seasonal variations in beach composition, a beach may present a trafficable surface during one period of the year and not during another.

BACKSHORE PROTECTION

As stated previously, procedures for minimizing the oil contamination of backshore areas should be instituted at the first indication of a possible shoreline-pollution event. The construction of a dike or berm along the upper-tidal zone could assist in preventing incoming tides from depositing oil onto backshore areas. During Phase II, several tests were conducted utilizing a D-6 bulldozer to construct berms in the upper-tidal zone. Berms, 6 to 7 ft wide and 2-1/2 to 3 ft high, could be constructed at the rate of 1,000 lin ft per hour. Observations of the tidal action on the constructed berms indicated that the berms could successfully protect backshore areas for at least one tidal cycle and possibly two, assuming no large storm waves or winds occur during the oil-contamination event. A trench on the seaward side of the berm would also assist in trapping oil that comes ashore on each wave for subsequent removal.

COST ANALYSIS

The cost per unit of oil collected, unit of beach material handled, and area cleaned (for the removal of a thin film of oil from a beach tidal zone) was calculated for each restoration procedure evaluated. These costs, tabulated in Table 30, were calculated from the cleaning rate data given in Table 26 and equipment rental rates and operator costs presented in Tables 39 and 40 in Section VI. The cost of moving the oil-contaminated sand to an unloading area is tabulated separately from the cost of transporting the material to disposal sites at various haul distances. The cost of a conveyor system to transfer material into trucks is included in the removal costs for restoration procedures utilizing motorized elevating scrapers. Those restoration procedures utilizing front end loaders are assumed to unload material directly into trucks. The beach-restoration procedures that provided the lowest removal costs are those that utilize a motorized elevating scraper singly or in combination with a motorized grader.

The removal cost per acre is the principal cost to be considered in planning beach-restoration operations. The cost per gallon of oil removed is a function of the initial oil loading and the cost per cubic yard removed is a function of the effectiveness of the equipment in making a thin cut with a minimum of spillage. The transport costs are a function of the amount of material removed to clean a beach area. The higher transport costs associated with restoration procedures utilizing front end loaders reflect the inefficiency of front end loaders in removing oil-contaminated material. Heavier initial oil loadings than the 0.5 gal/sq yd used in this test program would have little to no effect on the cleaning cost per acre if oil penetration is limited to 1 in. However, the removal cost per gallon of oil would decrease in proportion to the increase in oil loading.

The beach-restoration costs associated with the Santa Barbara, California, and Grand Island, Louisiana, oil-spill incidents were calculated from information reported in Refs. 25 and 34. The available data was inadequate for a complete cost analysis, but an approximation of the cost per acre of beach cleaned was made. At Santa Barbara, it was stated[25] that a work force of 50 men aided by 4 front end loaders, 2 bulldozers and 10 dump trucks could clean 1 mile of beach per 8-hour day. By applying the equipment rental rates listed on page 111 and the prevailing labor rates in the Santa Barbara area, a cleaning cost of $325 per acre was calculated for 1 mile of beach 75 ft wide, and $500 per acre for 1 mile of beach 50 ft wide. The cost of trucks was not included since not enough data were available on length of haul and number of trips per truck.

At Grand Isle, the restoration procedure involved the use of motorized graders operating in conjunction with front end loaders (see Restoration Procedure C, Table 31).

A work force of 1 motorized grader, 3 rubber-tired front end loaders, and 20 men cleaned 15 miles of beach in 4 days. The cleanup cost was calculated on the same basis used for the Santa Barbara incident. This yielded a cost of $140 per acre for 1 mile of beach 20 ft wide, and $170 per acre for 1 mile of beach 15 ft wide. As in the Santa Barbara calculation, trucking costs were not included because of insufficient data.

Comparison of these costs with those listed in Table 30 for the beach-restoration procedures evaluated in this program shows that the Grand Island costs are comparable to those calculated for the motorized grader-front end loader combination. The advantages of utilizing motorized elevating scrapers in beach-restoration operations is readily apparent when comparing the $108 per acre cost versus $325 to $500 per acre cost incurred at Santa Barbara, where a large amount of manual labor was utilized.

Table 30

COST SUMMARY(a)

(For Removal of Thin Film of Oil From Beach Tidal Zone)(b)

Restoration Procedure	Removal Cost			Transport Cost(c) ($/Acre) to Disposal Area at Indicated Distance			
				Miles			
	$\left(\frac{\$}{\text{cu yd}}\right)$	$\left(\frac{\$}{\text{gal}}\right)$	$\left(\frac{\$}{\text{acre}}\right)$	1	5	10	20
Combination of motorized grader and 9 cu yd motorized elevating scraper with 24-in. belt conveyor system	0.37	0.05	118	30	90	150	300
9 cu yd motorized elevating scraper with 24-in. belt conveyor system	0.32	0.045	108	32	93	161	321
Combination of motorized grader and 3 cu yd rubber tired front end loader	0.75	0.07	176	25	77	124	220
Combination of motorized grader and 2 cu yd tracked front end loader	2.50	0.19	450	20	60	96	173
Tracked front end loader	1.92	0.64	1,540	88	261	420	757

(a) based on 60-min working hour

(b) based on initial oil loading of 0.5 gal/sq yd

(c) based on 15-cu-yd-capacity trucks

SECTION VI

RECOMMENDED RESTORATION PROCEDURES

The Phase I evaluation tests indicated that several restoration procedures provided considerable savings in effort and cost over methods previously used. In Phase II, full-scale demonstration tests of each restoration procedure were conducted to evaluate the operating procedures and modifications selected in Phase I, and to determine the cost and effectiveness of each restoration procedure. As a result of the tests conducted in this study, the restoration procedures listed in Table 31 are recommended for use in the restoration of oil-contaminated beaches.

The surface conditions and topography of a beach contaminated with oil and the manner in which the oil has been deposited onto the beach will dictate the choice of equipment to be utilized and the operating procedures to be followed.

The restoration procedures described herein are those recommended for the restoration of relatively flat, sandy beaches contaminated under one or both of the following situations:

a. Beach material uniformly contaminated with a layer of oil up to the high-tide mark and/or deposits of oil dispersed randomly over the beach surface. Oil-deposit penetration is limited to approximately 1 in.

b. Agglomerated pellets of oil-sand mixture or oil-soaked material, such as straw and beach debris, distributed randomly over the surface and/or mixed into the sand.

The procedures tested utilize the following equipment, singly or in combination:

- Motorized Graders
- Motorized Elevating Scrapers
- Conveyor-Screening Systems
- Mulch Spreaders
- Front End Loaders

In the following sections, descriptions of each type of equipment are given, including (a) principle of operation, (b) applicability, including equipment modifications to improve effectiveness in restoration procedures on oil-contaminated beaches, and (c) operational procedures. Included in each section are tables of equipment specifications and operating costs obtained from equipment manufacturers. The tables do not include all models and makes in each equipment category; however, the listed models constitute the majority of such equipment presently

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Table 31

RECOMMENDED RESTORATION PROCEDURES

RESTORATION PROCEDURE	METHOD OF OPERATION
A. Combination of motorized grader and motorized elevating scraper	Motorized graders cut and remove surface layer of beach material and form large windrows. Motorized scrapers pick up windrowed material and haul to disposal area for dumping or to unloading ramp-conveyor system for transfer to dump trucks. Screening system utilized to separate beach debris such as straw and kelp from sand when large amounts of debris are present.
B. Motorized elevating scraper	Motorized elevating scrapers, working singly, cut and pick up surface layer of beach material and haul to disposal area for dumping or to unloading ramp-conveyor system for transfer to dump trucks. Screening system utilized to separate beach debris such as straw and kelp, from sand when large amounts of debris present.
C.* Combination of motorized grader and front end loader	Motorized graders cut and remove surface layer of beach material and form large windrows. Front end loaders pick up windrowed material and load material into following trucks. Trucks remove material to disposal area or to conveyor-screening system for separation of large amounts of debris from sand.
D.* Front end loader	Front end loaders, working singly, cut and pick up surface layer of beach material and load material into following trucks. Trucks remove material to disposal area or to conveyor-screening system for separation of large amounts of debris from sand.

* Utilize restoration procedures C and D only in instances where motorized elevating scrapers are not available. Operations of front end loaders on oil-contaminated beach areas should be kept to a minimum.

utilized in construction activities. A section is included that gives nationally averaged rental rates for the equipment recommended and operator costs for several selected cities.

MOTORIZED GRADERS

PRINCIPLE OF OPERATION

Motorized graders (Fig. 11) are designed to move quantities of material short lateral distances by the process of side casting. They are not generally used to haul material in the direction of travel. When the blade is set at an angle, the material that is cut and pushed ahead of it tends to be deflected to one side with a rolling and sliding action. The curve of the moldboard (blade) is designed to promote the rolling and sliding action of the material as it moves across the blade.

The size of the windrow created by the material as it comes off the blade is dependent upon the depth of cut, angle of the blade and the condition of the material being moved. Under certain soil conditions, a motorized grader is capable of making successive passes, i.e., picking up a windrow and simultaneously cutting and moving the cut material along with the previous windrow. After the windrows are formed, they must be removed from the area by some other means.

APPLICABILITY

Motorized graders are most efficient when operating on relatively flat areas of cohesive soil, firm but not hard, and on relatively long narrow areas. A uniform cut is difficult to maintain under conditions where rocks are present in the surface layer. For the removal of oil-contaminated sand, the motorized grader would be most efficiently used on the firmly packed beach area lying between the high and low tidal zones. If oil penetration is greater than 1 in., a motorized grader should be used only if motorized elevating scrapers are not available.

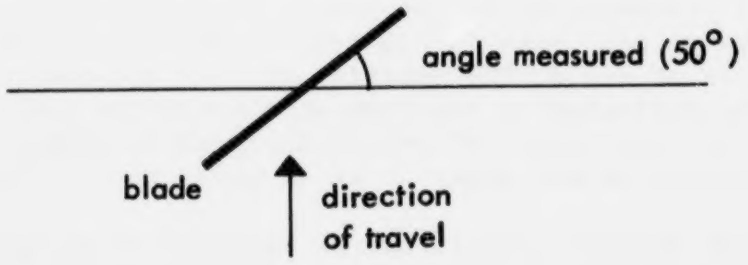
A major problem encountered with a motorized grader is its inability to maintain traction when operating on a beach of low-bearing-strength sand. Flotation tires, as shown in Fig. 16, on all wheels will overcome this problem on most beaches. A set of flotation tires and rims to fit most models and makes of motorgraders would cost approximately $2,400.

An alternative to flotation tires is the addition of forged steel alloy half-tracks, which would fit over the drive wheels and front wheels on each side of the motorized grader as shown in Fig. 34. These half-tracks are a standard shelf item and have been utilized extensively on agricultural machinery. A set of half-tracks can be installed for approximately $1,000.

OPERATIONAL PROCEDURES

Operational procedures for motorized graders conducting beach restoration operations follow:

(1) Set moldboard (blade) at a 50-deg angle from the perpendicular to the direction of travel.



(2) Set depth of cut at depth of oil penetration (1/2 to 1 in.).

(3) Operate grader in second gear (3 to 4 mph).

(4) Commence grading first pass on oil-contaminated material farthest inshore, casting windrow parallel to surfline. Continue grading to end of contaminated area or approximately 200 to 300 yards in distance.

(5) Return grader to starting point by backtracking on cleaned area.

(6) Reposition grader for second pass so as to pick up first-pass windrow and cast second-pass windrow parallel to surfline (see Fig. 43).

(7) Return grader to starting point by backtracking on cleaned area.

(8) Reposition grader for third pass so as to cast a windrow from surfline side onto first- and second-pass windrow, as shown in Fig. 44. A three-pass windrow is the optimum for pickup by a motorized elevating scraper (see Fig. 45). Limit height of windrow to ground clearance of tractor.

Note: Optimum rate of operation for smooth firm beaches is 1/2 to 1/3 hr/acre.

Specifications of motorized graders are given in Table 32. Equipment manufacturer designations are given in Table 33.

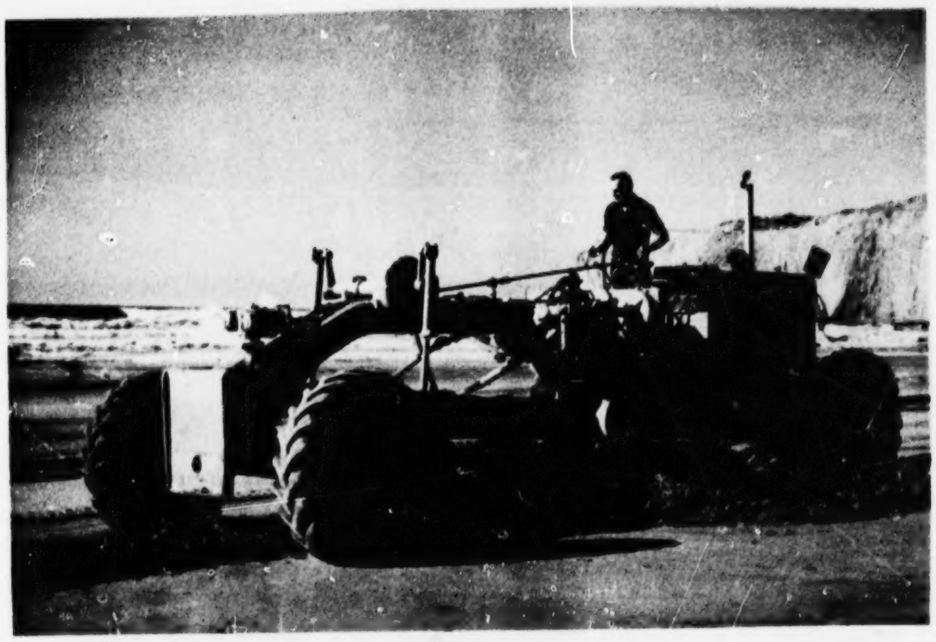


Fig. 43. Motorized Grader Casting Second-Pass Windrow

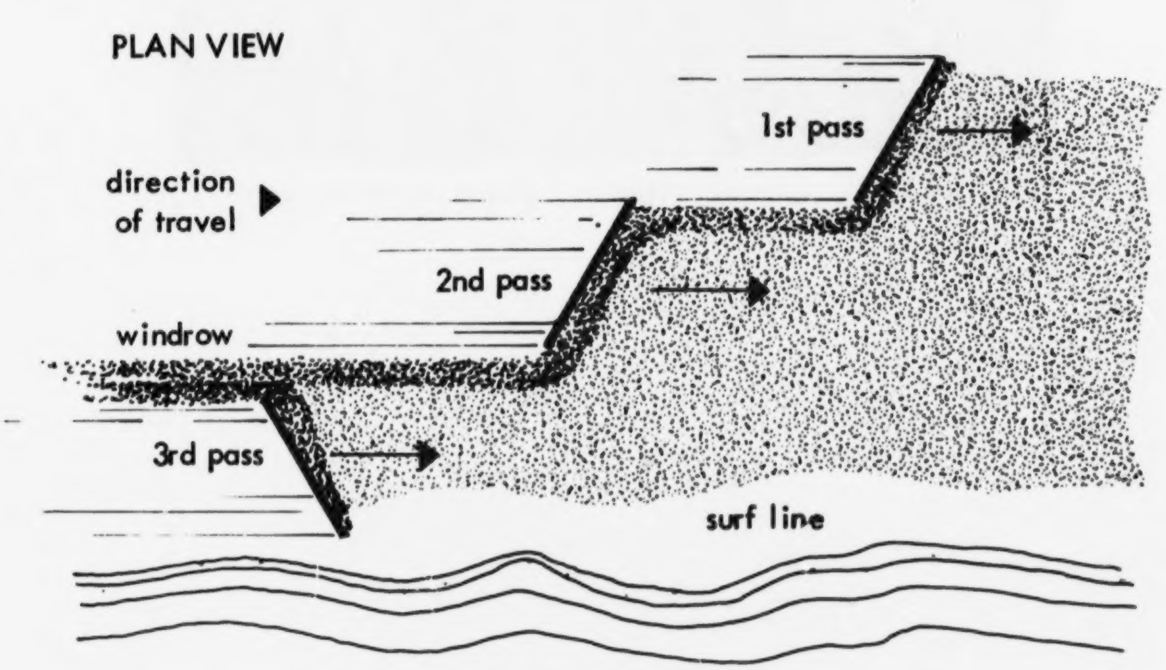

PLAN VIEW
1st pass
direction of travel
2nd pass
windrow
3rd pass
surf line

Fig. 44. Motorized Grader Operational Sequence

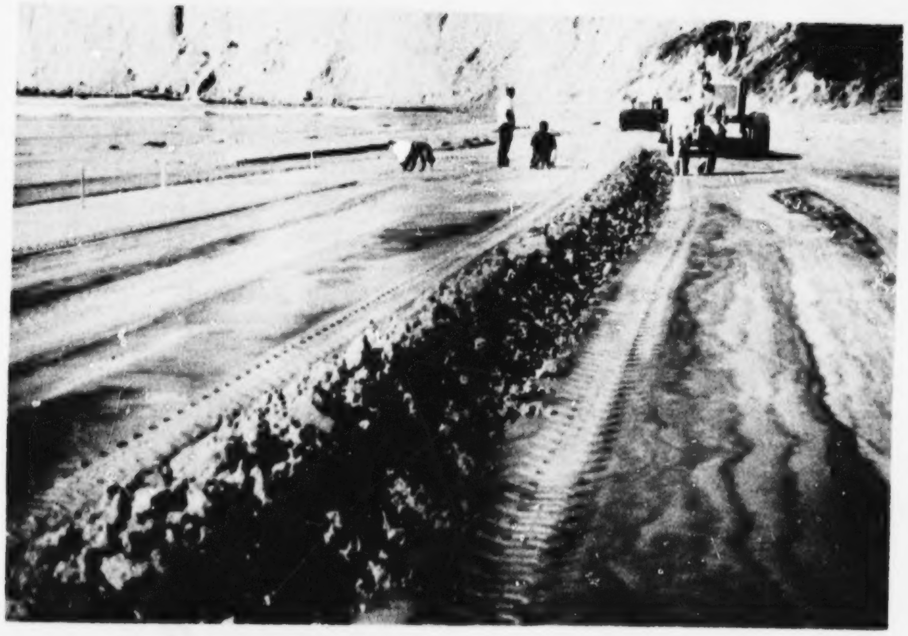


Fig. 45. Three-Pass Windrow Formed by Motorized Grader

Table 32

EQUIPMENT SPECIFICATIONS: MOTORIZED GRADERS

TYPE : Wheeled, self-propelled to operating site

Make & Model	Net Engine HP Rating	Weight including attachments (tons)	Blade Size	Rating - chain speed (ft/min)	Labor Requirements (man-hrs per hour of equipment operation)		Fuel, Oil & Lube Reqmts. (per hour of equipment operation)		
					Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
CAT - 16	225	24	14'x31"	Not Applicable	1	.28	10.0	.4	.22
WABCO 888	230	20	14'x32"		1	.28	10.1	.4	.22
WABCO 777	160	14.5	12'x28"		1	.25	7.0	.3	.16
Galion T 600	175	14.5	13'x26"		1	.25	7.5	.3	.18
AW Super 500	179	15	13'x28"		1	.25	7.5	.3	.18
WABCO 330 H	100	11	12'x25"		1	.2	4.5	.25	.10
AW Super 200	106	11	12'x24"		1	.2	5.0	.25	.10
CAT 12F	115	13	12'x24"		1	.2	5.0	.30	.11
Galion 104H	125	12	12'x24"		1	.2	5.5	.30	.12
Galion 118	135	12.5	12'x24"		1	.22	6.0	.30	.13
AW Pacer 400	143	13.5	13'x26"		1	.25	6.5	.30	.14
WABCO 440 H	147	12	12'x25"		1	.25	7.0	.30	.14
CAT - 14E	150	15	13'x27"		1	.25	7.1	.30	.15
AC-M-100B	127	13	12'x24"		1	.2	5.5	.30	.12
AW Super 100	106	10	12'x24"		1	.2	5.0	.25	.10
AW Super 300	143	12.5	13'x26"		1	.25	6.5	.30	.14
CAT 112F	100	10.5	12'x24"		1	.2	4.5	.25	.10
CD D-560	100	12.5	12'x25"		1	.2	4.5	.25	.10
CD D-562	125	13	12'x25"		1	.2	5.5	.30	.12

(continued)

Table 32 Continued

EQUIPMENT SPECIFICATIONS: MOTORIZED GRADERS

TYPE: Wheeled, self-propelled to operating site

Make & Model	Net Engine HP Rating	Weight including attachments	Blade Size	Rating - chain speed	Labor Requirements		Fuel, Oil & Lube Reqmts.		
					(man-hrs per hour of equipment operation)		(per hour of equipment operation)		
		(tons)		(ft/min)	Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
CD D-640	135	14	12'x25"		1	.22	6.0	.30	.13
CD D-650	160	14	12'x25"		1	.25	7.0	.30	.16
Galion 104 B	106	11.5	12'x24"		1	.20	4.5	.25	.10
" 160 B	160	13.5	12'x27"		1	.25	7.0	.30	.16
" 160 L	190	14.5	12'x27"		1	.27	8.3	.35	.18
Huber D-1100	107	11.5	12'x24"		1	.20	5.0	.25	.10
" D-1300	130	12.5	12'x26"		1	.24	5.8	.27	.13
" D-1500	150	13.5	12'x26"		1	.25	7.1	.30	.15
" D-1700	165	14.5	12'x28"		1	.25	7.3	.32	.16
" D-1900	195	16	12'x28"		1	.28	8.6	.35	.18
Pettibone-402	125	11.5	12'x24"		1	.20	5.5	.30	.12
" -502	145	13.5	12'x24"		1	.25	6.7	.30	.14
Wabco - 440	115	12	12'x25"		1	.20	5.6	.30	.11
" 660-B	150	14	12'x28"		1	.25	7.1	.30	.15
" 666	132	13	12'x25"		1	.24	5.9	.27	.13

Table 33

EQUIPMENT MANUFACTURER DESIGNATIONS

NAME OF MANUFACTURER	DESIGNATION
Caterpillar Tractor Company	CAT
Allis Chalmers Mfg. Company	HD or AC
Eimco Corporation	Eimco
International Harvester Company	TD or IH
Euclid Div., General Motors	EUC
Michigan; Clark Equipment Company	Michigan
Hough; International Harvester Company	Hough
R.G. LeTourneau Inc.	LET
Pettibone Mulliken Corp.	Pettibone
Trojan Div., Eaton Yale & Towne Inc.	Trojan
Scoopmobile Inc.	Scoopmobile
WABCO, Construction Equipment Div.	WABCO
Austin Western; Baldwin Lima Hamilton Corp.	AW
Galion Iron Works & Mfg. Company	Galion
Hancock Div., Clark Equip. Company	Hancock
John Deere & Company	JD
[illegible] Mfg. Company	[illegible]
Huber Machinery Division	Huber
Cleveland [illegible] Corporation	[illegible]
General Motors Earthmoving Division	GM
MRS Manufacturing Co.	MRS

Note: Mention of commercial products does not imply endorsement by the Federal Water Quality Administration or URS Research Company.

MOTORIZED ELEVATING SCRAPERS

PRINCIPLE OF OPERATION

Motorized elevating scrapers (Fig. 12) are utilized to pick up and haul material short distances, then dump and spread. They are equipped with self-loading elevators that pick up the cut material and dump it back into the hopper. In some materials, such as sand, they pick up material more easily than a standard non-elevating scraper, which relies on the resistive force of the undercut material to fill the hopper.

APPLICABILITY

Motorized elevating scrapers are most effective in clearing large, relatively flat areas; however, they can operate on sloped beaches. The motorized elevating scraper is the most efficient type of equipment for picking up windrows left by a motorized grader. The maximum size of the windrow should be restricted to the height of the ground clearance of the tractor, which ranges from 12 to 24 in. for most tractors.

On beaches exhibiting low bearing strength, the motorized elevating scraper, in its present configuration, will become immobilized in the sand. Two possible methods that will overcome the immobilization problem are:

(1) Use of a non-self-propelled elevating scraper (see Table 35), pulled by a tracked bulldozer, as shown in Fig. 30. The use of a crawler tractor increases traction greatly and would permit scraper operation on beaches of low-bearing strength.

(2) Use of a pusher unit (i.e., a tracked or wheeled bulldozer) as an additional prime mover to push the elevating scraper unit, or use of a tandem-drive elevating scraper, such as the WABCO BT 33F, which has both pusher and puller prime mover units as standard equipment.

When utilizing the motorized elevating scraper for removing windrows or making a thin cut, major spillage occurs in the gap between the edge of the elevator flights and the side of the bowl. Under normal earthmoving operations, this is considered slight and is ignored; however, in beach-restoration operations, this spillage would prove unacceptable. In cooperation with the International Harvester Co., a sand baffle system has been designed to fit in the back of the motorized elevating scraper. These baffle plates attach to each side of the bowl behind the elevator flights. The design and position of the baffle plates relative to the scraper bowl are shown in Fig. 32. As indicated, the plates are designed to close the 12-1/2-in. gap between the end of the elevator flights and the inside of the scraper bowl. The baffle system can be prefabricated and field-installed. The design can be adapted to fit elevator hoppers of other makes and models. Figure 33 shows the baffle plates installed in the motorized elevating scraper evaluated in this study.

The cost of prefabrication and installation of these baffle plates was approximately $300.

OPERATIONAL PROCEDURES

Operational procedures for motorized elevating scrapers working singly or in combination with a motorized grader are listed below. Since a motorized grader is capable of producing windrows continuously, several motorized elevating scrapers can be utilized simultaneously to pick up windrows.

- Operating in combination with motorized graders
  (1) Position elevating scraper to straddle the windrow formed after two or three passes by the motorized grader (see Fig. 46). Lower cutting edge of bowl to cut to depth of oil penetration (1/2 in.).

  (2) Operate the scraper in first gear (low range) and pick up windrow until bowl has filled up. When bowl is full, stop scraper and pick up bowl, keeping elevator flights moving.

  (3) Stop elevator flights and proceed to unloading area.

- Operating singly
  (1) Commence operations on oil-contaminated material farthest inshore. Operate parallel to surfline. (See Fig. 47).

  (2) Set depth of cut to depth of oil penetration (1 to 2 in.) or just to skim surface if only oil-contaminated debris to be removed. Figures 48 and 49 show the results of picking up beach debris, and Figs. 50, 51 and 52 show the results of removing straw from a test area. Figure 53 shows the elevating scraper removing oil-sand pellets from a test area.

  (3) Operate scraper in first gear (low range).

  (4) Length of pass dependent upon size of scraper bowl. When bowl is full, stop scraper and pick up bowl, keeping elevator flights moving.

  (5) Stop elevator flights and proceed to unloading area.

Note: Rate of operation for one elevating scraper is 45 min to 1 hr/acre when removing windrows and 1 hr/acre when operating singly. Rates are based on a haul distance of 200 ft (see Fig. 19). Table 34 lists the specifications of the motorized elevating scraper. Table 35 presents a similar listing for the crawler tractor-drawn elevating scrapers.

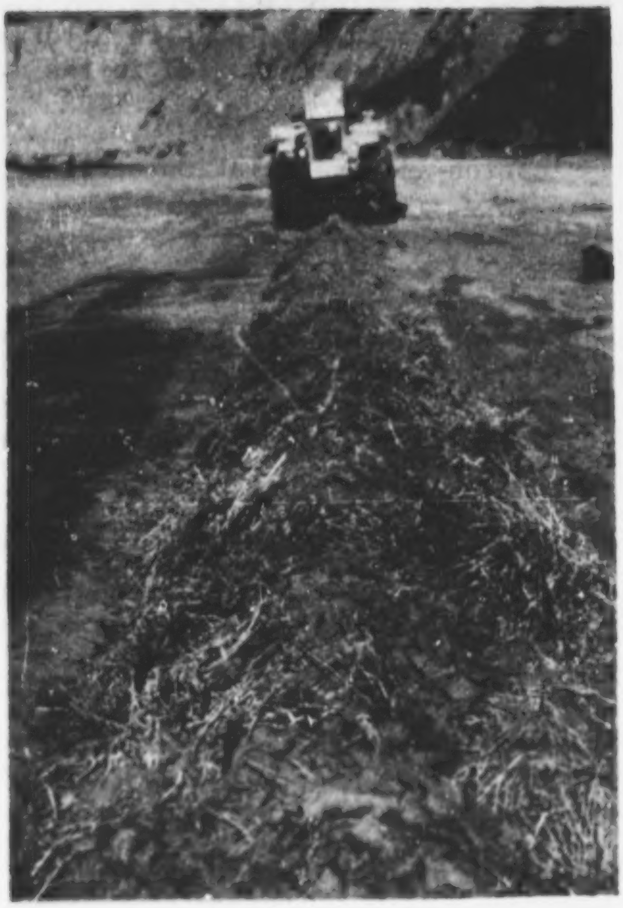


Fig. 46. Motorized Elevating Scraper in Position to Remove Windrow

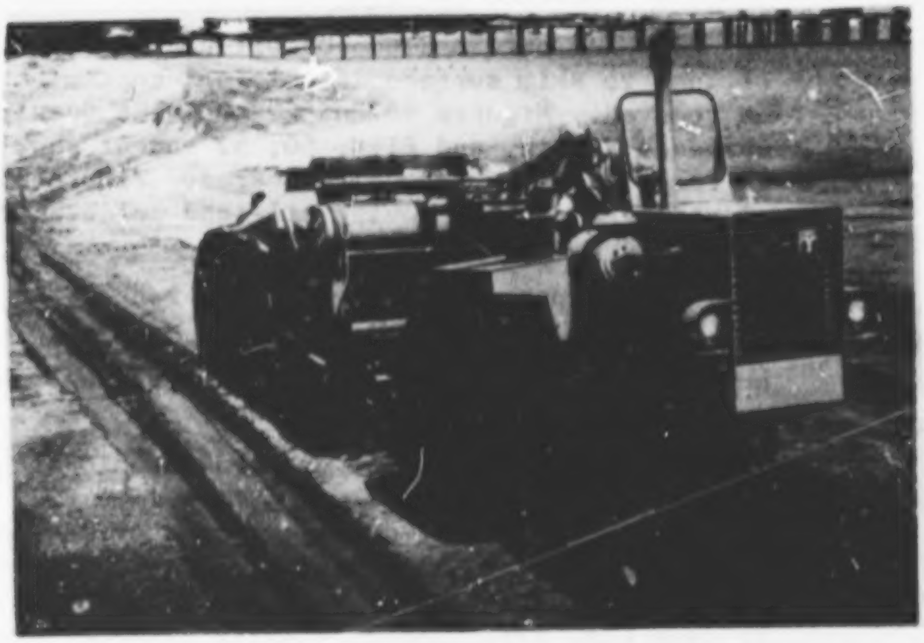


Fig. 47. Motorized Elevating Scraper Removing Thin Film of Oil

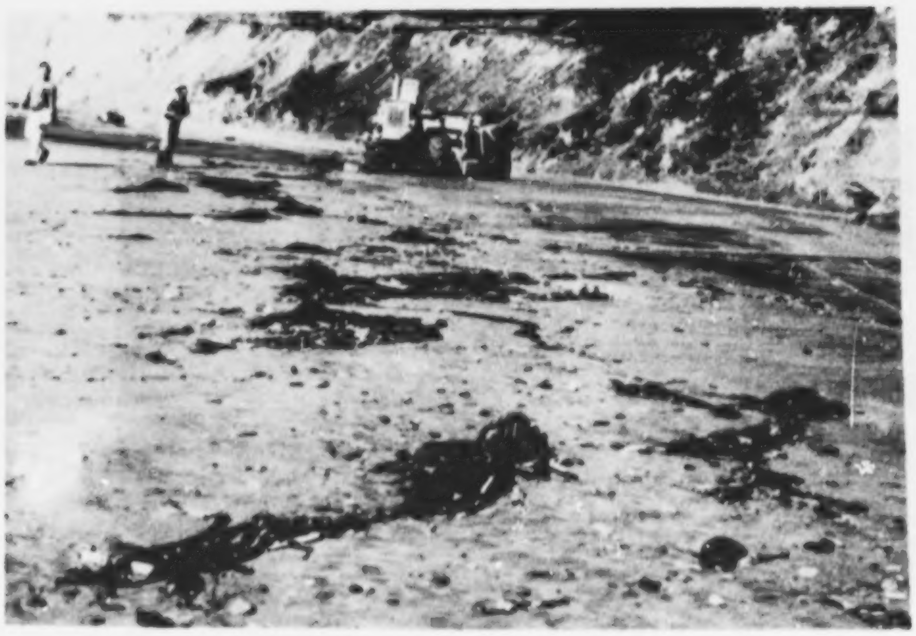


Fig. 48. Beach Debris Prior to Removal by Motorized Elevating Scraper

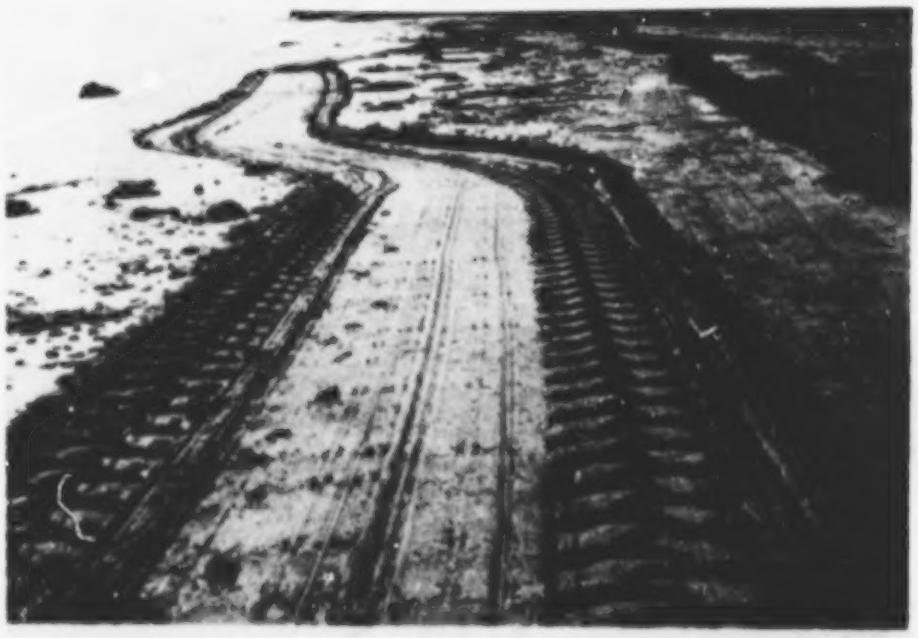


Fig. 49. Beach After Removal of Debris by Motorized Elevating Scraper

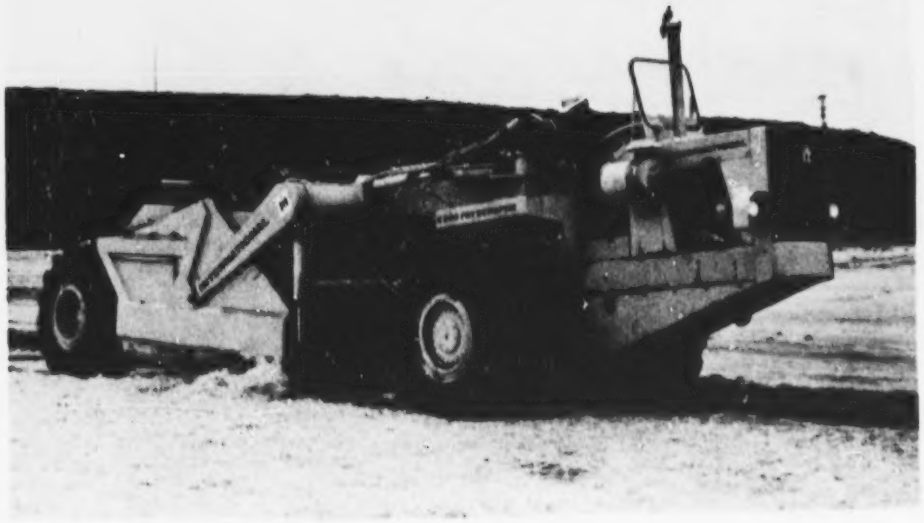


Fig. 50. Motorized Elevating Scraper Removing Oil-Straw Mixture

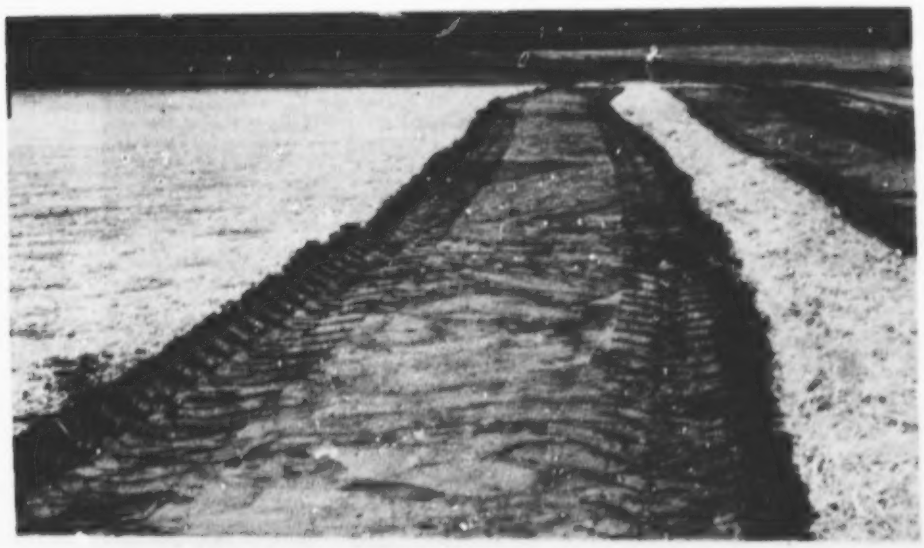


Fig. 51. Test Area after Two Passes with Motorized Elevating Scraper

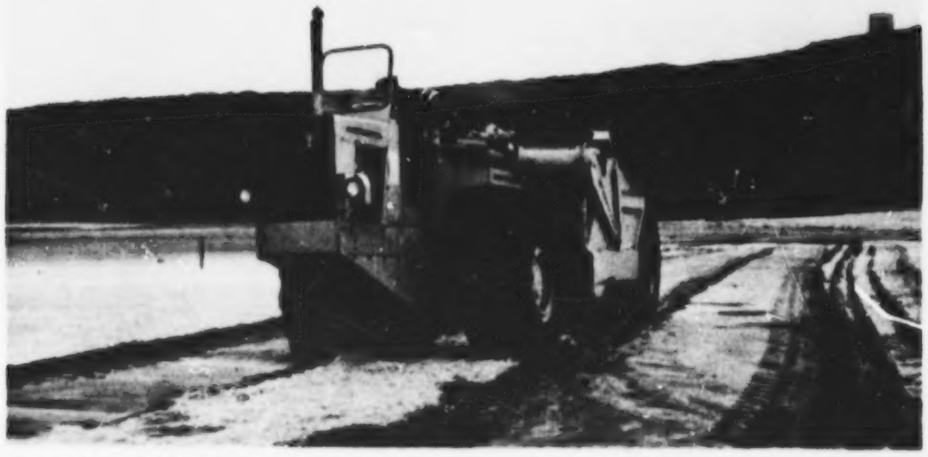


Fig. 52. Motorized Elevating Scraper Making Third Pass on Test Area Contaminated with Oil-Straw Mixture

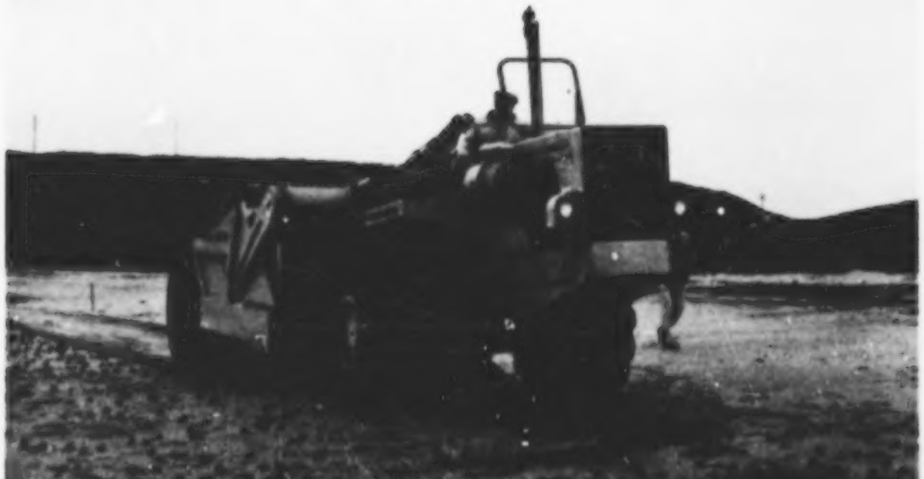


Fig. 53. Motorized Elevating Scraper Removing Oil-Sand Pellets from Test Area

Table 34

EQUIPMENT SPECIFICATIONS: MOTORIZED ELEVATING SCRAPERS

TYPE: See below

Make & Model	Net Engine HP Rating	Weight including attachments	Capcaity	Rating - chain speed	Labor Requirements		Maintenance Requirements		
					(man-hrs per hour of equipment operation)		(per hour of equipment operation)		
		(tons)	(cu yds)	(ft/min)	Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
SELF-PROPELLED to Operating Site									
IH - E 200	135	13	9	166	1	.35	4.8	.5	.15
IH - E 211	157	14	11	{155 206	1	.35	7.0	.45	.16
CAT - 613	150	14	11	225	1	.35	7.0	.45	.16
GM S-7	148	16	12		1	.35	7.0	.45	.16
Hancock - HF 6	64	10	6		1	.3	2	.43	.05
" 282 G	115	13.5	9		1	.34	4	.47	.13
" 292 B	160	16.5	11		1	.36	7	.50	.18
Michigan 110-12	178	19	12		1	.37	8.5	.52	.21
MRS - 1 - 905	186	18	12		1	.37	8.5	.52	.21
Wabco - D - 111A	160	18	11		1	.36	7	.50	.18
TRANSPORTATION REQUIRED to Operating Site									
JD - 860	228	21	15	200	1	.40	10.0	.55	.16
IH - E 270	260	25	21		1	.45	9.0	.60	.30
CAT J-621	300	31	21	{202 172	1	.45	13.5	.60	.30
IH - E 295	420	44	32		1	.50	15.0	.7	.33
CAT - 633	400	43	32		1	.50	15.0	.7	.33

(continued)

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Table 34 Continued

EQUIPMENT SPECIFICATIONS: MOTORIZED ELEVATING SCRAPERS

TYPE: See below

Make & Model (continued)	Net Engine HP Rating	Weight including attachments (tons)	Capacity (cu yds)	Rating - chain speed (ft/min)	Labor Requirements (man-hrs per hour of equipment operation)		Maintenance Requirements (per hour of equipment operation)		
					Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
TRANSPORTATION REQUIRED to Operating Site									
AC 260 E	320	30	24		1	.45	13.7	.65	.32
GM 35E	495	49.5	35		1	.55	16.2	.75	.36
Michigan - 110 - 14	238	21	14		1	.4	10.8	.56	.27
" 210 - H	335	28	23		1	.46	14.0	.65	.33
" 310 - H	475	47	31		1	.53	16.1	.74	.36
MRS I- 95 S	250	28.5	17.5		1	.41	11	.57	.27
" I - 100 S	290	32	20.5		1	.43	12.6	.60	.30
" I - 105 S	337	36.5	23		1	.46	14.0	.65	.33
" I - 110 S	389	39	25		1	.49	15.1	.68	.34
WABCO - C 222-F	318	29	21		1	.45	13.7	.65	.32
" B 333-F	475	47	32		1	.53	16.1	.74	.36
* " BT 333-F	{475 475	57	34		1	.8	32.2	1.48	.72
*Has dual engines.									

Table 35

EQUIPMENT SPECIFICATIONS: TRACTOR-DRAWN ELEVATING SCRAPER

TYPE: Wheeled, transportation required tc operating site

Make & Model	Net Engine HP Rating	Weight including attachments (tons)	Capcaity (cu yds)	Rating - chain speed (ft/min)	Labor Requirements (man-hrs per hour of equipment operation)		Fuel, Oil & Lube Reqmts. (per hour of equipment operation)		
					Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
Hancock 4R2	40	2.5	4	Not Applicable	1				
Soilmover - 50 E	40-55	3	5		1				
Hancock 8R4	70	6	8		1				
Soilmover - 90 E	55-75	5-1/2	8-1/2		1				
Hancock 11 E	90	11	11		1				
Hancock 14 E	120	12-1/2	14		1				
Hancock 18 E	170	19-1/2	18		1				
Soilmover - 130 E	70	4	13		1				
Johnson - 40-B	50	3	4		1				
Johnson - 80-C	70	5	8		1				
Johnson - 110-B	70	6	11		1				
Johnson - 410-B	100	7	11		1				

FRONT END LOADERS

PRINCIPLE OF OPERATION

Front end loaders are designed for digging, loading, and limited transport of material. The front loader (bucket) may be carried by any type of tractor, crawler tractor (Fig. 15), or four-wheel-drive or two-wheel-drive rubber-tired tractors (Fig. 28). Crawler tractors and four-wheel-drive tractors are used for heavy service and two-wheel-drive models for lighter work.

Buckets are made in different sizes and weights for various types of materials and work conditions. Bucket capacity will depend upon the size and type of tractor on which it is mounted. Buckets for crawler tractors range from 3/4 to 4 cu yd. Wheeled tractors have both smaller and larger buckets.

The bucket is loaded by the forward travel of the tractor. Most loading is done with the bucket flat or tilted at a slight downward angle. The flat position is best for loading a quantity of loose material. The amount picked up in the bucket will vary with the consistency of the material, the slope of the area worked on, and the skill of the operator.

APPLICABILITY

From the results obtained during the preliminary evaluation tests conducted in Phase I, and analysis of previous beach-restoration operations, it is recommended that front end loaders be utilized only for loading into trucks material from stockpiles or from windrows formed by motorized graders. Their operations on oil-contaminated beach areas should be kept to a minimum, especially when utilizing crawler-tractor-mounted front end loaders, which have been found to grind the oil several feet into the sand.

Front end loaders equipped with slot buckets could be utilized in removing large quantities of oil-contaminated debris, such as kelp, driftwood, etc. Slot buckets would allow loose sand to fall away through the slots.

OPERATIONAL PROCEDURES

Operational procedures for front end loaders working singly or in combination with a motorized grader are listed below. Several front end loaders will be required to remove windrows formed by a single motorized grader.

(1) Utilize 4-in-1 type bucket if available (see Fig. 54).

(2) Operate tractor in first gear while loading.

(3) To minimize spillage while scraping, fill bucket only 1/3-1/2 full.

(4) Minimize traffic over oil-contaminated area when using tracked loader.

Note: Rate of operation for one front end loader removing windrows over an average haul distance of 100 ft is 2-1/2 to 3 hr/acre.

Table 36 presents specifications of rubber-tired and self-propelled front end loaders. Table 37 presents specifications of the crawler front end loader.

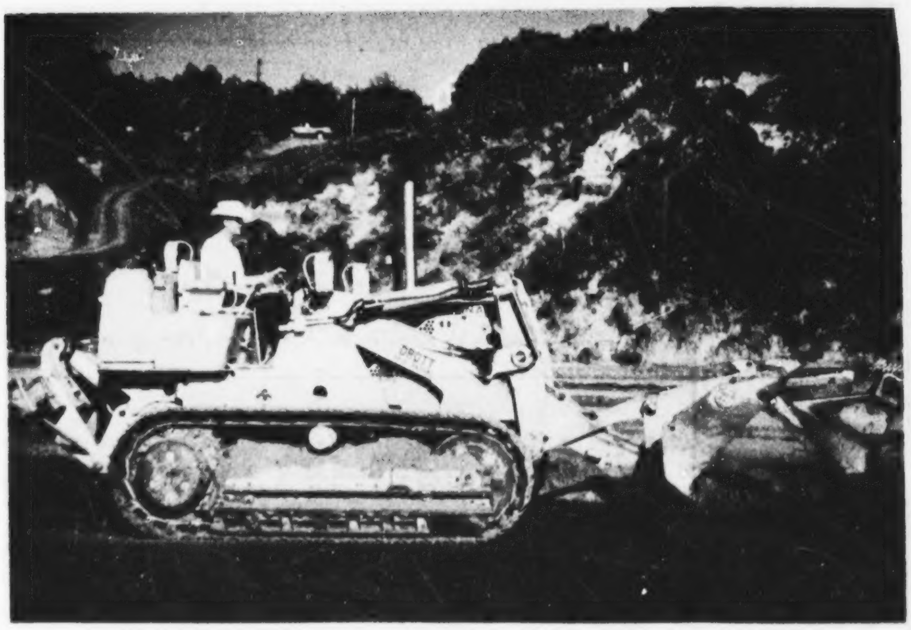

Fig. 54. 4-in-1 Bucket in Clamshell Position

Table 36

EQUIPMENT SPECIFICATIONS: FRONT END LOADER

TYPE: Wheeled, self-propelled to operating site

Make & Model	Net Engine HP Rating	Weight including attachments	Capacity	Rating - chain speed	Labor Requirements (man-hrs per hour of equipment operation)		Fuel, Oil & Lube Reqmts. (per hour of equipment operation)		
		(tons)	(cu yds)	(ft/min)	Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
CAT - 944	105	11	2	Not Applicable	1	.22	5.0	.3	.11
Michigan 75-111	108	8.5	2		1	.22	5.0	.3	.11
Pettibone 125A	108	8.3	1-3/4		1	.22	5.0	.3	.11
Trojan 164A	115	9	2		1	.22	5.1	.3	.11
EUC 72-21	115	9.5	2		1	.22	5.1	.3	.11
CAT - 950	125	11.5	2-1/4		1	.25	5.5	.3	.12
Michigan 85-111	140	10	2-3/4		1	.27	6.5	.4	.14
Hough H-65C	141	11.5	2-1/4		1	.27	6.5	.4	.14
EUC 72-31	145	12	2-1/2		1	.27	6.5	.4	.14
CAT - 966	150	16	3		1	.30	6.5	.5	.15
EUC 72-41	163	14.5	3		1	.35	7.5	.6	.16
Pettibone PM-440	175	16	3-1/2		1	.36	7.5	.6	.17
Pettibone PM-350	185	16	3-1/2		1	.38	8.5	.6	.18
Trojan - 3000	185	15	3-1/2		1	.41	8.5	.6	.18
Hough H-900	198	17	3		1	.41	9.0	.7	.19
EUC - 202	200	16	3-1/2		1	.42	9.5	.7	.19
HD-745	210	18	5		1	.35	9.5	.7	.20
Michigan 125 - 111A	220	18	4		1	.35	10.0	.7	.21
Hough H 1008	226	20	4		1	.34	10.0	.7	.22
CAT - 980	235	22	4		1	.35	11.0	.7	.23
Michigan 175 - 111	238	18	4-1/2		1	.40	11.0	.7	.23
Trojan - 4000	247	22	4-1/2		1	.40	11.5	.7	.24
Michigan 175 - 111A	290	21.5	5		1	.42	13.5	.7	.29
Hough H-120C	296	32	5		1	.42	13.5	.8	.30
CAT - 988	300	33	5-1/2		1	.42	13.7	.8	.31
Trojan - 404	318	25	5		1	.45	14.5	.8	.33
Scoopmobile 500	320	31.5	5		1	.45	14.5	.8	.33
Michigan 275 - 111A	380	31.5	6-1/2		1	.49	17.0	.9	.40

Table 37

EQUIPMENT SPECIFICATIONS: FRONT END LOADER

TYPE: Crawler, transportation required to operating site

Make & Model	Net Engine HP Rating	Weight including attachments (tons)	Capacity (cu yds)	Rating - chain speed (ft/min)	Labor Requirements (man-hrs per hour of equipment operation)		Fuel, Oil & Lube Reqmts. (per hour of equipment operation)		
					Equipment Operator	Maint. & Repair	Diesel Fuel (gal)	Lube (lb)	Oil (gal)
HD - 7-G	100	12	1-3/4	Not Applicable	1	.22	4.5	.5	.10
CAT - 955K	115	14	1-3/4		1	.22	5.0	.5	.11
IH - 175B	120	13.5	2		1	.22	5.5	.6	.12
EIMCO - 123C	150	19	2-3/8		1	.33	7.0	.6	.15
EIMCO - 115	154	21	1-1/2		1	.33	7.0	.6	.15
IH - 250B	160	19.5	2-1/2		1	.29	7.2	.6	.16
CAT - 977K	170	20.5	2-1/2		1	.28	7.5	.7	.17
HD - 12-G	185	21	2-3/4		1	.32	8.5	.7	.18
EIMCO - 126C	218	28	3		1	.35	10.0	.7	.21
HD - 21-G	254	37	4		1	.37	11.5	.9	.25

UNLOADING RAMP AND CONVEYOR SYSTEM

PRINCIPLE OF OPERATION

An unloading ramp and conveyor system, as shown in Fig. 55, should be considered as a method of transferring beach material picked up by motorized elevating scrapers directly into trucks or onto stockpiles. The system can also include a screening system to separate oil-soaked debris, such as straw, from the oil-sand mixture.

APPLICABILITY

The use of an unloading ramp-conveyor system is dependent upon the magnitude of the beach-restoration operations. In situations similar to that encountered during the Santa Barbara incident, where some 4,000 truckloads of oil-contaminated sand and debris were hauled to disposal areas, a system of this type would have saved considerable cost and effort.

Several such systems may have to be installed if oil contamination occurs over a significant length of beach. The hauling time from the operating area to the unloading area is a factor that has to be considered in locating such a facility.

DESIGN AND CONSTRUCTION

A typical ramp system, such as that shown in Fig. 55, consists of two cribs constructed of railroad ties, placed on either side of a pit excavated to receive the hopper of the conveyor system. The cribs are then backfilled with material (soil, sand, gravel) and ramps constructed. The ramps and cribs contain approximately 100 cu yd of material, which may be found on site or brought in. Figure 56 shows the cribs in position and Fig. 57 shows the completed ramp prior to placement of the conveyor system.

Railroad ties are placed across the top of the crib and spiked down with timber spikes. Railroad rails are used to bridge the opening between the cribs and are welded to bearing plates bolted to each crib. Figure 58 shows the construction details for a typical unloading ramp installation.

Table 38 lists the specifications of suitable conveyors. A screening system can be attached to the discharge end of the conveyor system, if required.

Factors that would influence the selections of the conveyor-screening system and design of the unloading ramp include:

- Conveyor capacity - estimated volume of material per hour that will be produced by beach-restoration procedures.

- Conveyor length - height above ground required to load trucks.
- Hopper capacity - hopper should have sufficient capacity to receive total load of largest elevator scraper utilized.
- Screening system - condition of material removed by beach-restoration procedures, e.g., oil-sand mixture, oil-sand-straw mixture, debris, and oil-sand pellets.
- Ramp height - depends on overall height of conveyor and hopper and depth of pit, if required.
- Ramp width - maximum width of largest elevating scraper utilized.
- Ramp opening - length of bowl opening of largest elevating scraper utilized.

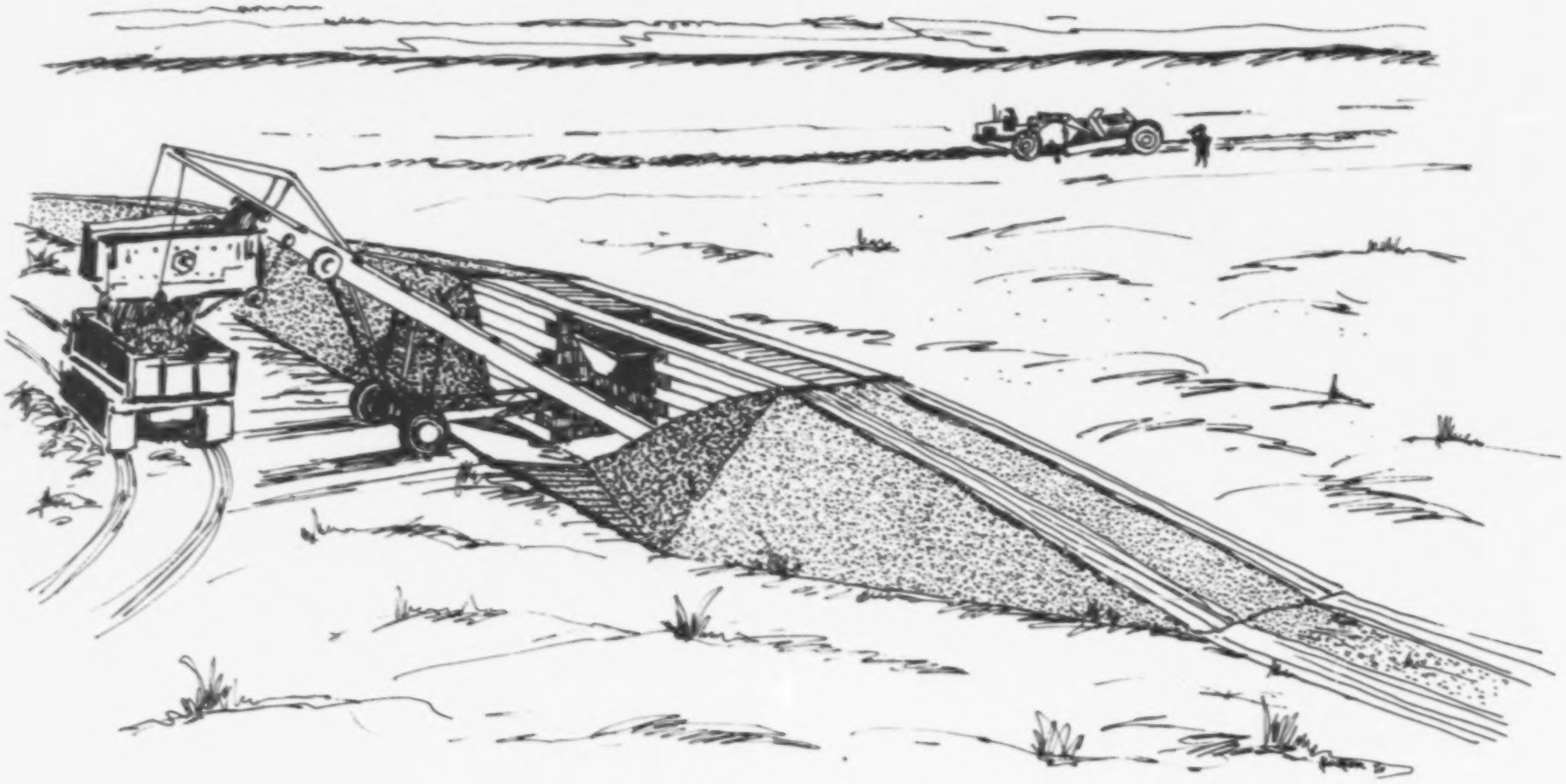

Fig. 55. Unloading Ramp and Conveyor-Screening System

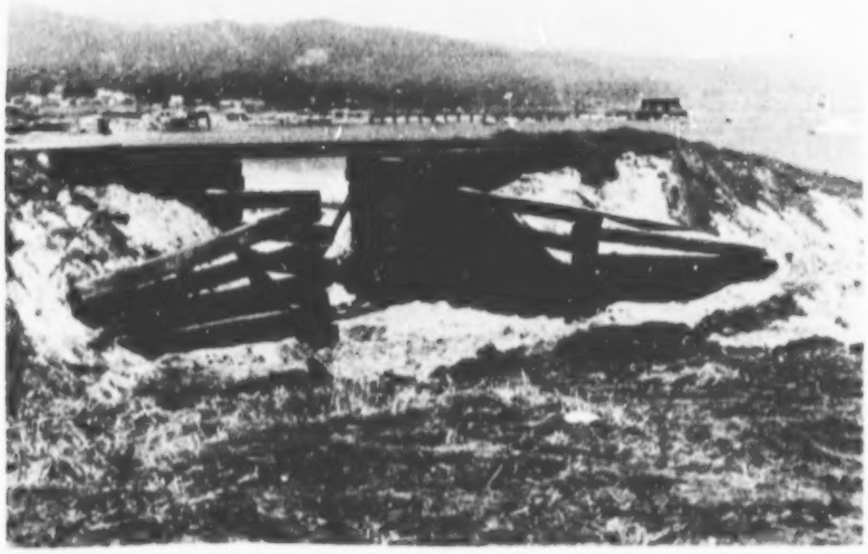

Fig. 56. Railroad Tie Cribs

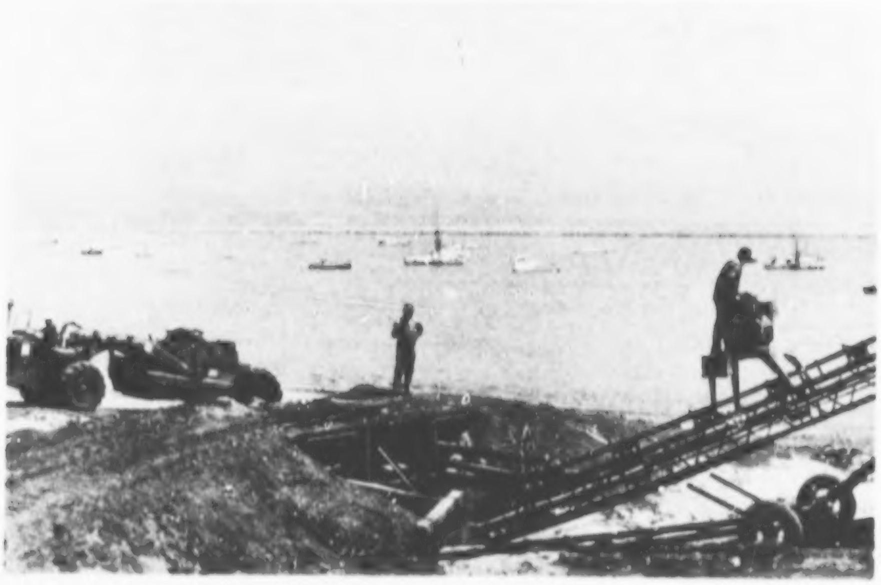

Fig. 57. Unloading Ramp.

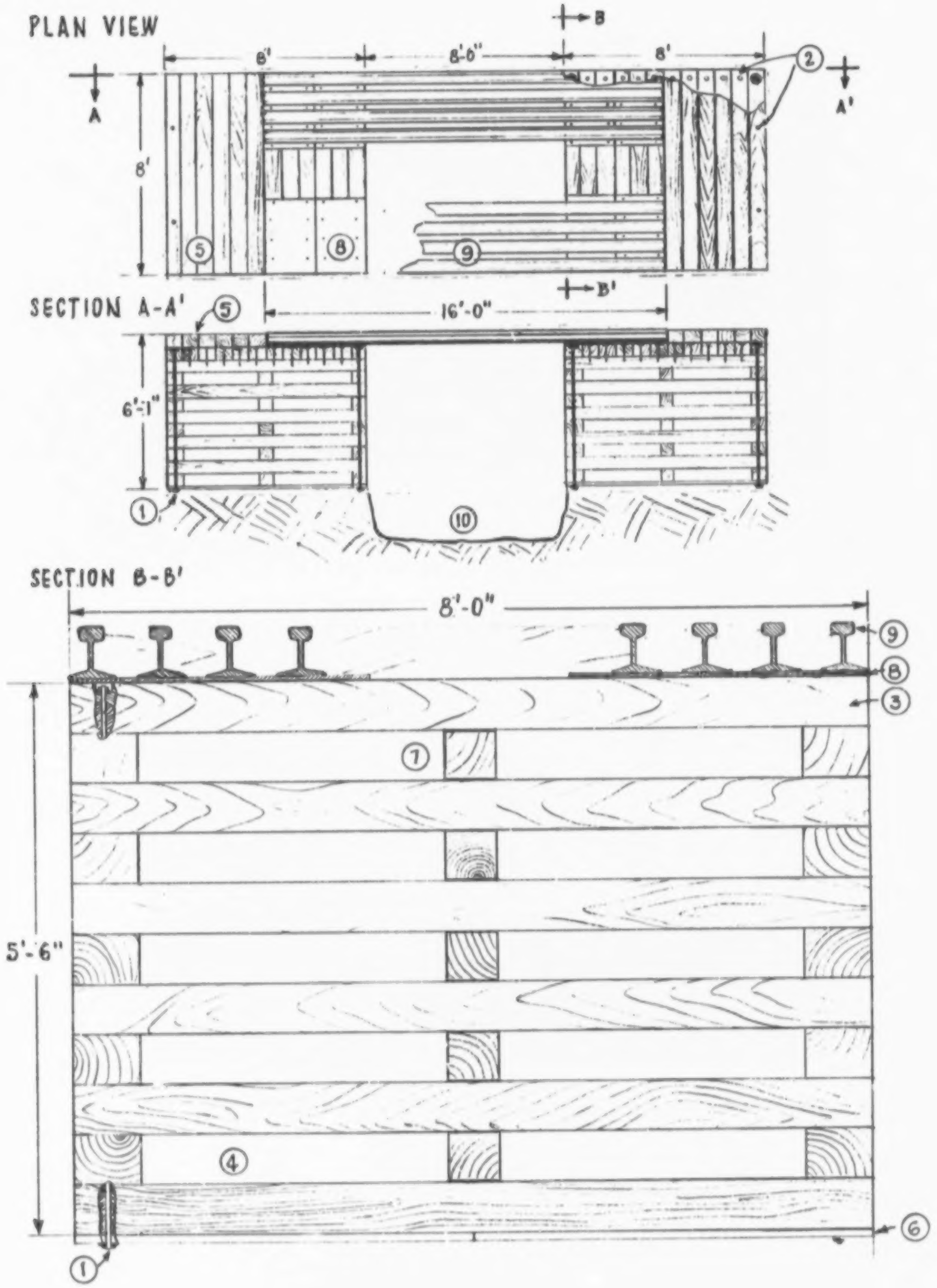
PLAN VIEW
B
A
A'
8'
8'-0"
8'
8'
②
⑤
⑧
⑨
SECTION A-A'
⑤
16'-0"
B'
6'-1"
①
⑩
SECTION B-B'
8'-0"
⑨
⑧
③
⑦
5'-6"
④
⑥
①

Fig. 58. Unloading Ramp - Construction Details

Figure 58b

CONSTRUCTION NOTES FOR UNLOADING RAMP

① Drift bolts, 1/2" x 6' countersunk below top of crib, one at each corner of crib.

② Timber spikes, 3/8" x 10"

③ Railroad ties, 6" x 8" x 8' or equivalent, with holes for drift bolts drilled near ends.

④ Backfill cribs and construct earth ramps with on-site material if suitable. Approximately 100 cu.yd. fill required for ramps and backfill.

⑤ Top layer laid in except for tie proximal to ramp, which is spiked in place.

⑥ Plywood, 4' x 8' x 1"

⑦ Sections of railroad tie, approx. 6" long, wedged in place.

⑧ Steel bearing plates, 8 each - 2' x 3' x 1/2", spiked or lag bolted in place.

⑨ Railroad tracks, 100 lb/ft, welded to bearing plates.

⑩ Excavate as required for conveyor system.

Table 38

EQUIPMENT SPECIFICATIONS: BELT LOADERS

Type: Wheel, transportation required to operating site

Make and Model	Net Engine HP Rating	Weight including attachments (tons)	Capacity cu yds/hr	Width of Belt (in.)	Labor Requirements (man hrs/hr of equipment operations)		Fuel, Oil, Lube Requirements (per hour of equip. operation)		
					Equipment Operator	Maintenance and Repair	Diesel Fuel (gal)	Lube (lbs)	Oil (gal)
Barber-Greene PL-90	130	24	2000	48	1	.26	5.6	.3	.12
Hewitt-Nobins-450	170	28.5	2400	48	1	.28	7.5	.7	.17
Ko-Cal 4845-R	105	19	2800	48	1	.22	5.0	.3	.11
Ko-Cal 4860-R	154	25.5	2800	48	1	.30	6.5	.5	.15
Ko-Cal 4845-S	105	24	1800-2800	48	1	.22	5.0	.3	.11
Ko-Cal 4860-5	154	29	1800-2800	48	1	.30	6.5	.5	.15
Ko-Cal 4860-S	154	29	1800-2800	48	1	.30	6.5	.5	.15
Ko-Cal 3650	70	11.5	1200	36	1	.2	4.0	.3	.10
Ko-Cal 4250	97	13	1700	42	1	.22	4.5	.5	.10
Kolberg 348-50	130	24.5	2000	48	1	.26	5.6	.3	.12
Kolberg 448-60	154	20	2000	48	1	.30	6.5	.5	.15
Kolberg 1136-50	70	9.5	1000	36	1	.2	4.0	.3	.10
Kolberg 1148-50	130	15	2000	48	1	.26	5.6	.3	.12
Pioneer 4841	100	45.5	2000	48	1	.22	4.5	.5	.10

MULCH SPREADERS
(Straw Blowers)

PRINCIPLE OF OPERATION

Mulch spreaders (Fig. 31) are designed specifically for the fast distribution of mulch materials to assist in the control of soil erosion. They are equipped with a discharge spout designed to move a full 360 deg horizontally and 75 deg vertically, thus allowing the operator to spread the mulching material without repositioning the mulcher. The unit is trailer mounted and requires towing.

APPLICABILITY

Straw has been the most widely used material for absorbing oil, on both water and on beach areas. The use of mulch spreaders (straw blowers) for the rapid dispersal of straw is recommended for use on oil contaminated beach areas where oil has not penetrated into the beach.

On beach areas, the straw blower requires a four-wheel-drive vehicle or a tracked vehicle for towing purposes. A platform for the handling of straw, such as a trailer, is also required.

EQUIPMENT AND OPERATOR COSTS

Nationally averaged rental rates for the equipment recommended for use in beach restoration operations are given in Table 39. These rental rates do not include the cost of an operator and costs of fuel and lubricants. In addition to being national averages in dollar amounts, the rental rates reflect an averaging of age, condition and operating efficiency of the equipment.

It is general practice to base rates upon one shift of 8 hr per day, 40 hr per week, or 176 hr per month of a 30-consecutive-day period. Many distributors do not rent by the day or by the week, especially in the case of large equipment. If the equipment is rented by the day, the rate for overtime is 1/8 the daily rate for each hour in excess of 8. If it is rented by the week, the rate for overtime is 1/40 the weekly rate for each hour in excess of 40. If it is rented by the month, the overtime rate is 1/176 the monthly rate for each hour in excess of 176 in any one 30-consecutive-day period.

Operator costs are tabulated in Table 40 for selected cities. These rates include fringe benefits. Overtime costs for operators are normally computed to be 150% to 200% of his straight-time wages.

In many instances, equipment and operators will be obtained through an earthmoving contractor, and the rental rates will include equipment rental, operator costs, maintenance costs, fuel, oil, and contractor's overhead and profit. An example* of such rental rates is listed below:

Equipment Type	Hourly Rate
Motorized grader - 26,000 lbs	$22.00
Motorized elevating scraper - 9 cu yd	25.00
Front end loader - 1-3/4 cu yd	20.00
Bulldozer - D-6	22.00
Dump truck - 8 cu yd	14.25

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* Rates quoted by Andreini Bros., Inc., Half Moon Bay, California.

Table 39
NATIONALLY AVERAGED RENTAL RATES
(Excluding Costs of Operator and Fuel)

		per month	per week	per day
		MOTOR GRADER		
		Diesel engine w/direct drive		
Net weight (lb)				
up to 10,000		542.00	186.00	61.75
10,001 to 20,500		650.00	217.00	70.00
20,501 to 22,500		*	*	*
22,501 to 26,000		1070.00	359.00	110.00
26,001 to 28,000		1167.00	*	*
		Diesel engine w/torque converter		
22,501 to 26,000		1326.00	436.00	142.00
26,001 to 28,000		1383.00		
28,001 to 30,000		1480.00	471.00	152.00
		MOTORIZED ELEVATING SCRAPER		
		2-wheel tractor with 2-wheel scraper		
HP range	Rated capacity (cu yd)			
121-144	8-9	1740.00	559.00	165.00
145-190	10-12	1973.00	700.00	229.00
191-288	13-19	2478.00	833.00	*
250-300	20-27	3445.00	1173.00	394.00
400-500	28-32	4829.00	1511.00	444.00
		4-wheel tractor with 2-wheel scraper		
121-144	8-9	1732.00	584.00	157.00
145-190	10-12	1990.00	625.00	193.00
		FRONT END LOADER/CRAWLER		
		Diesel engine-direct drive manual shift		
Rated capacity (cu yd)				
3/4		703.00	228.00	*
1		794.00	268.00	67.25
1-1/4		918.00	307.00	85.25
1-1/2		1035.00	357.00	109.00
2		1150.00	424.00	*
2-1/4		1513.00	533.00	168.00
		Diesel engine-torque converter, manual shift		
1		797.00	270.00	76.25
1-1/2		1135.00	359.00	*
2-1/4		1567.00	570.00	*

Continued

Table 39 (Contd)
NATIONALLY AVERAGED RENTAL RATES
(Excluding Costs of Operator and Fuel)

Rated capacity (cu yd)	per month	per week	per day
Diesel engine-torque converter, power shift			
1	808.00	285.00	80.00
1-1/4	984.00	345.00	101.00
1-1/2	1202.00	383.00	115.00
1-3/4	1585.00	467.00	143.00
2	1593.00	502.00	163.00
2-1/2	2107.00	730.00	241.00
2-3/4	2325.00	800.00	270.00
FRONT END LOADERS — WHEELED			
Gasoline engine-torque converter, power shift			
1	661.00	226.00	68.50
1-1/4	760.00	249.00	78.25
1-1/2	910.00	294.00	84.75
2	1009.00	354.00	111.00
2-1/2	1039.00	362.00	115.00
Diesel engine-torque converter, power shift-rigid frame			
1	735.00	245.00	81.75
1-1/4	836.00	283.00	84.75
1-1/2	985.00	321.00	99.75
2	1153.00	397.00	119.00
2-1/2	1388.00	446.00	141.00
2-3/4	1475.00	487.00	156.00
3	1602.00	572.00	176.00
3-1/2	1730.00	598.00	184.00
4-1/2	2138.00	725.00	224.00
5	2536.00	775.00	*
6	2933.00	991.00	*
Diesel engine-torque converter, power shift-articulated steering			
2	1205.00	414.00	142.00
2-1/2	1448.00	520.00	164.00
2-3/4	1600.00	588.00	196.00
3	1827.00	622.00	201.00
3-1/2	1993.00	657.00	208.00
4	2425.00	803.00	255.00
4-1/2	2464.00	825.00	266.00
5	3222.00	1035.00	313.00
6	3268.00	1086.00	317.00
10	5667.00	*	*

Continued

Table 39 (Contd)
NATIONALLY AVERAGED RENTAL RATES
(Excluding Costs of Operator and Fuel)

Rated Capacity (cu yd)	per month	per week	per day
2-wheel drive gasoline engine-direct drive, manual shift			
1/2	424.00	*	*
5/8	518.00	170.00	55.25
3/4	518.00	170.00	55.25
1-1/2	607.00	184.00	58.25
Gasoline engine, torque converter, power shift			
5/8	504.00	182.00	58.25
3/4	572.00	193.00	65.25
1-1/4	719.00	249.00	88.00
Diesel engine-direct drive, manual shift			
1/2	442.00	151.00	42.00
5/8	566.00	195.00	55.00
3/4	566.00	195.00	55.00
1	672.00	220.00	57.00
BELT LOADING CONVEYORS (Belt width 12-18 in.)			
conveyor length (ft)			
20- 26	213.00	72.50	24.25
26- 30	*	*	*
30- 36	291.00	98.75	38.25
36- 46	350.00	123.00	45.50
46- 56	468.00	163.00	57.50
Belt width 18-24 in.			
30- 36	363.00	125.00	43.00
36- 46	483.00	161.00	53.25
46- 56	521.00	163.00	*

*Insufficient information received.

Source: Nationally Averaged Rental Rates, compiled by Associated Equipment Distributors.

Table 40

EQUIPMENT OPERATOR WAGE RATES FOR SELECTED CITIES
($/hr + fringe benefits. As of June 1, 1970)

	Classification			
City	Tractor/F.E. Loader	Motorized Scraper	Motorized Grader	Truck Driver
Atlanta	5.35+ .30	5.35+ .30	4.85+ .30	3.50
Baltimore	5.22+ .50	5.67+ .50	5.67+ .50	3.25+ .23
Birmingham	4.70+ .20	4.70+ .20	4.70+ .20	4.70+ .20
Boston	6.94+ .59	6.94+ .59	6.94+ .59	5.15+ .45
Dallas	5.80+ .35	5.80+ .35	5.80+ .35	
Los Angeles	6.41+1.20	6.41+1.20	6.51+1.20	6.31+1.20
New Orleans	5.75+ .25	5.75+ .25	5.75+ .25	4.80
New York	7.10+1.70	6.37+ .99	6.05+ .96	4.99+1.29
Philadelphia	6.25+ .56	6.25+ .56	6.88+ .56	4.32+ .49
San Francisco	6.66+1.45	6.66+1.45	6.40+1.45	6.58+1.43
Seattle	6.93+ .70	6.87+ .70	6.82+ .70	6.60+ .72

Source: Engineering News-Record, 5/28/70

SECTION VII

ACKNOWLEDGMENTS

Acknowledgment must be given to the outstanding cooperation and assistance provided by: The State of California Department of Parks and Recreation for their permission to utilize the beach test areas along the San Mateo County coast; the San Mateo County Harbor Commission for their permission to utilize the beach test areas within the Half Moon Bay Harbor breakwater; the Union Oil and Standard Oil Companies for providing the necessary crude oil for the test program.

The authors gratefully acknowledge the support and guidance given by personnel from the Federal Water Quality Administration, specifically, Mr. Gerald L. Burke, who served as Project Monitor, and Mr. Harold Bernard and Mr. Ralph L. Rhodes of the Agricultural and Marine Pollution Control Branch.

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APPENDIX A

SHORELINE OIL POLLUTION EVENTS

A review of existing reports on recent oil-pollution incidents resulting in beach contamination was conducted to determine:

- (a) The magnitude of beach contamination.
- (b) Clean-up procedures utilized to restore the contaminated beach areas.
- (c) Costs (manpower and equipment) associated with the clean-up operations.

In addition, persons from organizations that had participated in the cleanup of the beaches at Santa Barbara were interviewed to obtain information pertinent to beach-restoration operations. It was very quickly determined that there was insufficient information to accurately determine the cost and effectiveness of previous beach-restoration operations.

The most prominent recent oil-pollution events resulting in beach contamination are those involving the groundings of the tankers, Torrey Canyon and Ocean Eagle, and the rupture at the Santa Barbara offshore oil well. Some of the more significant information from these and five other beach-pollution events are summarized in Table A-1. Additional information on these incidents can be found in the references listed in Table A-1. These three prominent crude oil spills resulted in the pollution of important recreational beaches. They were also given notoriety through the news media, so that great public pressure was brought to bear demanding immediate and massive cleanup efforts. A brief description of these three major incidents follows:

TORREY CANYON

The SS Torrey Canyon ran aground on the Seven Stones rocks, approximately 16 miles west of the southwestern tip of England. At the time of grounding, she was carrying 119,000 tons of Kuwait crude oil. Crude oil began leaking from the day of stranding, March 18, 1967, and continued until the ship was destroyed by bombing on March 29 and 30, 1967.

The first oil carried to English beaches on March 25, 8 days after the grounding. Oil reached the coast of Guernsey on April 6 and first reached the shores of Brittany on April 9 and was still coming ashore on April 28. Other offshore islands were also polluted.

A massive effort was made to contain the oil or destroy it at the ship. Petroleum-based detergents were used to dissipate the oil just before it arrived at the beaches or after it was on the beaches. Table 2 shows the quantities of emulsifier-solvent mixtures used during the

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Table A-1

BEACH OIL-POLLUTION OCCURRENCES

EVENT	TORREY CANYON GROUNDED S.W. ENGLAND	OCEAN EAGLE GROUNDED SAN JUAN, PUERTO RICO	OFFSHORE WELL A-21 (TRACT 402) BLOWOUT SANTA BARBARA	WITWATER HULL FAILURE LOS MINOS BAY, CANAL ZONE	HAMILTON TRADER COLLISION WALES	ARROW GROUNDED NOVA SCOTIA	GRAND ISLE, LOUISANA (Unknown source)	DELIAN APOLLON GROUNDED ST. PETERSBURG, FLORIDA
Date	18 Mar 67	3 Mar 68	28 Jan 69	13 Dec 68	30 Apr 69	4 Feb 70	25 Jun 70	13 Feb 70
Oil type and amount spilled (gal)	Kuwait crude $15x10^6$ of the $36x10^6$ cargo	Venezuelan crude $3.5x10^6$ of $5.6x10^6$ cargo	Summerland 2.10^6 at 21,000/day, then 2,100/day	Bunker C $125x10^3$ Diesel $50x10^3$	Fuel Oil $200x10^3$	Bunker C $8.4x10^5$	Unknown	Bunker C $5\text{-}10x10^3$
Clean-up costs	$\$7.2x10^6$	$700,000	$\$4.62x10^6$ (to Jun 69)					$\$2x10^6$ Suit filed
Weathering time	1 week	1-2 days	8 days +	2-3 days	2 weeks	3-4 days		2-3 days
Appearance	Water-in-oil emulsion	Black paraffin-like	Greenish black, asphaltic	Water-oil emulsion	Semi-hardened patches or lumps	Heavy, very tar-like	Oily emulsion	Heavy, black sticky
Miles of beach contaminated	75-175	5-25	50	Extensive (coral reefs)	40-50	80	7-15	~ 20
Depth of penetration of sand beach	12 in. deep (Whitesand Bay) oily layer 10 in.	12 in. deep (San Juan Bay) oily layer 6 in.	1 in. deep (oily layers 2 to 4 in.)	- - -			1 in. layer	1/2-in. layer
Notes	Wreck occurred 15 miles from Lands End	Grounded 300 yd north of harbor entrance	Well is 5.5 miles offshore	Broke up 3.5 miles east of Panama Canal Harbor breakwater	Collision with other vessel in Liverpool Bay	Went aground on Cerberus Rock in Chedabucto Bay	Source of contamination unknown	Run aground in Tampa Bay Shipping Channel
References	3,13,19,20,21	22,23,24	1,25,26,27,28	29,30	31	32,33	33,34	33,35,36,37

Table A-2

QUANTITIES OF EMULSIFER-SOLVENT MIXTURES USED DURING THE TORREY CANYON EMERGENCY[3]

(Up to 6 April 1967)

MAKE[†]	PROPORTION* EMULSIFIER (%)	ATOMATIC* CONTENT (%)	AMOUNT ISSUED (Thousand gallons*)		
			SEA USE	SHORE USE	TOTAL QUANTITY
BP 1002	20	66	250	540	790
Dasic	25	High	180	400	580
Gamlen	30	24	36	75	111
Dutch	--	--	66	--	66
Atlas	30	8	5	45	50
Petrofina	8	15	15	34	49
Basol	15	82	4	44	48
Gramos	--	--	25	20	45
Other Makes	--	--	11	6	17
Total (thousand gallons)			692	1,164	1,756

[†] Emulsifier-solvent mixtures as supplied. Mention of commercial products does not imply endorsement by the Federal Water Quality Administration.

[*] Information from Admiralty Oil Laboratory.

Torrey Canyon emergency. The greatest quantity was used on the oil after it came ashore.

Beach restoration methods utilized during the Torrey Canyon incident fell into three main groups: (a) dispersing the oil by spraying with emulsifier dissolved in solvent (detergent); (b) burning the oil, either in situs or after collecting it in heaps; and (c) physical removal of the oil or oil-contaminated sand.

DISPERSAL BY DETERGENT

On the basis of studies[38] conducted by the Warren Springs Laboratory, a volume of detergent equal to some 25% of the total volume of the oil deposited was applied to the contaminated beaches by spraying. The final step in this cleaning procedure was a liberal hosing down with water or flushing by the incoming tide. This method was found to be satisfactory during the early stages when the oil was coming ashore as a relatively thin fluid. Later when oil was washed ashore as a heavy water-in-oil emulsion (containing up to 80% water), detergents did not work satisfactorily.

It was noted that when detergents were used to clean heavily contaminated beaches, some of the emulsion sank deeply into the beach, forming a quicksand. The movement of sand and pebbles also covered up lumps of oily sludge which reappeared later as a result of the natural movement of the sands by tidal action.

BURNING

The major portion of beach contamination consisted of weathered oil, i.e., oil that had lost its more volatile fractions and had formed a water-in-oil emulsion. This contaminant proved extremely difficult to burn.

The most successful results were obtained when the emulsion was first broken down with detergent and the released oil then heated and burned. Some pools of oil were ignited by means of a flame-thrower or by pouring a solvent into the pool, mixing, and lighting. It was concluded that burning was too expensive and inefficient.

PHYSICAL REMOVAL

Many parts of the English coast were not accessible to wheeled vehicles and it was rarely possible to physically remove the oil. In some areas, however, conventional sewage tanker trucks were used to suck up pools of oil from coves and beaches. Bulldozers were used in a few instances to push the oil-contaminated sand into the ocean or to turn over that which had been treated with detergents.

On the north coast of Brittany, the oil was reported to have sunk into the sand to a depth of about 4 to 6 in. Bulldozers were used to remove the oil-contaminated sand by pushing it into the sea. In one instance, two four-wheel-drive motorized elevator scrapers were used to pick up the oil-contaminated sand and haul it to a nearby area for use as fill material. No data on rates or costs of operating this heavy equipment were reported.

OCEAN EAGLE

The oil tanker, Ocean Eagle, ran aground in the mouth of San Juan Bay on March 3, 1968. The ship broke in half, spilling approximately 3-1/2 million gal. of oil. Half of this oil went inside of the bay and half went to the coastal side of Puerto Rico. The north-bay shore of San Juan was polluted with the crude oil, as were several miles of beaches along the "Gold Coast," an important tourist area of Puerto Rico. An estimated 25 miles of beaches were polluted. Emulsifiers were spread around the wreck for 4 days in order to dissipate the crude oil. After this time, Ekoperl 33, a hydrophobic absorbent powder, was used to absorb the petroleum floating in the water. The mixture of Ekoperl and oil was then collected as it arrived on shore.

Booms and other barriers were found to be ineffective in keeping oil off the beaches. Strong wave action and the relative fragility of the boom and barriers limited their effectiveness.

The crude oil that reached the beach zone outside of San Juan Bay coated the sand and rocky coasts with a thin layer of black, aromatic, paraffin-like substance that had lost most of the volatile fraction. The principal restoration effort involved physical removal of the contaminated oil-sand mixture. A labor force of 270 men worked 10 to 12 hours a day, manually raking and scraping the contaminated sand into piles on the beach, where front end loaders placed the material into dump trucks for removal to a disposal site.

In some areas, where detergents were used to disperse the oil close to shore, a "quicksand" condition resulted, requiring the removal of sand to a depth of several feet, and its replacement by sand from other beaches.

In some cases, crude oil accumulated to a thickness of 6 in. Restoration of these beaches involved the removal of the sand to a depth of several feet and its replacement by clean sand.

SANTA BARBARA

On January 28, 1969, during and following normal well-drilling operations at Union Oil Company's Platform A in federal waters off the coast of Santa Barbara, California, oil and gas erupted from the ocean floor. The platform is located about 5 miles offshore.

The first contamination of beaches with oil occurred during a storm on the 4th and 5th of February. Approximately 30 to 50 miles of beach were eventually polluted with oil.

The priorities established for the cleanup of the coastline were as follows: (1) marinas, (2) public beaches, (3) less accessible public beaches, (4) private beaches, and (5) breakwater and rock riprap.

Beach restoration was generally accomplished by spreading straw on the deposited oil, collecting the oily mixture, and hauling it to disposal sites. Collection of the oily straw was primarily accomplished manually, raking the straw into piles and loading the mixture into dump trucks with front end loaders. Under these circumstances, according to T. H. Gaines,[25] 50 men aided by 4 front end loaders, 2 bulldozers, and 10 dump trucks could clean 1 mile of beach per 8-hour day.

Straw was spread on the beaches, in the tidal zone, both before and after the oil reached the shore. Straw mulchers* were found to be very effective in rapidly dispersing straw. No effective way was found for picking up the straw. A motorgrader was equipped with a row of tines attached to the moldboard and was used to rake up the straw. This proved to be ineffective and resulted in the burial of a major portion of the oil-contaminated mixture of straw and sand.

Burning of the oil-soaked straw on the beaches generally was ineffective and was suspended in some areas because of air pollution regulations.[25]

On one beach area in which oil had been mixed into the sand to a depth of several feet during loading operations with a crawler tractor-mounted front end loader, bulldozers were utilized to push the oil-contaminated sand into the surf.**

Oil that came ashore on the sand spit at the Santa Barbara Harbor entrance was subsequently covered with fresh uncontaminated sand as a result of the along-shore movement of beach material in this region. It has been reported*** that heavy waves and storms during the winter of 1969-70 uncovered oil buried in several locations during the February, 1969, operations.

The total work force involved in the restoration of the Santa Barbara beaches, in oil containment and removal of oil from harbor and offshore waters, numbered some 1,000 men. A supervisory force of 36 men utilizing a radio network was required to coordinate this massive operation. Some 3,000 tons of straw were dispersed over the contaminated beaches and on offshore waters. A total of 125 pieces of mechanical equipment, 54 boats of all types, and 18,900 ft of booms were utilized.

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* Powered straw blowers normally used for spreading straw on highway cuts and fills to prevent soil erosion.

** Private communication, Park Superintendent, City of Santa Barbara.

*** Private communication, U.S. Coast Guard, Santa Barbara, California.

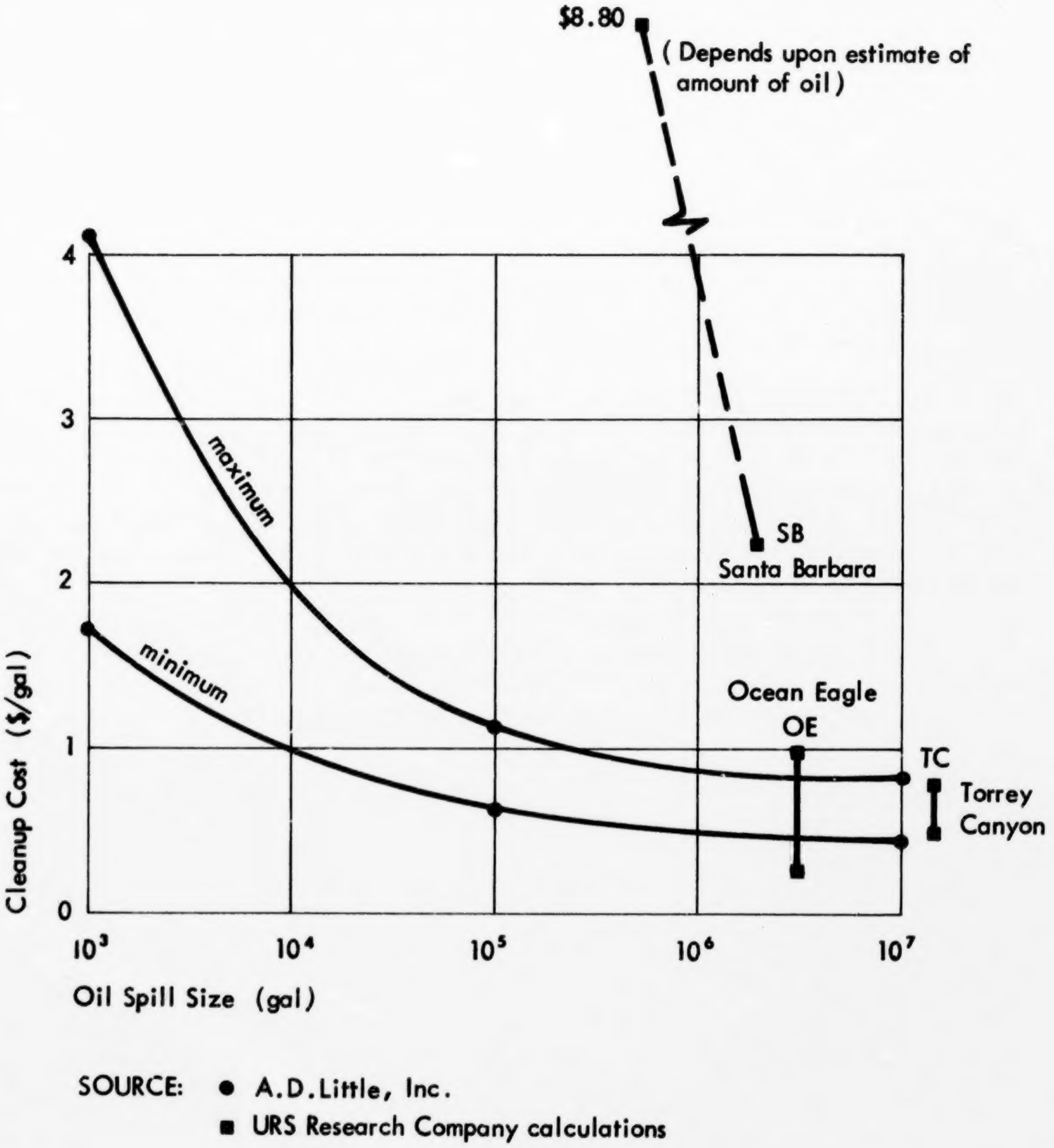


Fig. A-1. Beach Cleanup Cost Analysis

BEACH RESTORATION COSTS

Detailed information on the cost and effort (manpower and equipment) utilized in previous beach-restoration operations has not been discovered and probably does not exist. Generally, only overall costs have been reported. Thus the costs associated with onshore operations cannot be separated from the total costs. The results of a cost analysis by Arthur D. Little, Inc.[39] are shown graphically in Fig. A-1. Maximum and minimum cost ($/gal.) are given for cleanup of oil spills ranging from 10^3 to 10^7 gal. Included are data points for the *Torrey Canyon*, *Ocean Eagle*, and Santa Barbara incidents. For these incidents, reported costs as well as the estimates of amount of oil spilled were found to vary. Maximum and minimum cleanup costs for each incident were calculated.

The Santa Barbara cleanup costs per gallon of oil are shown to be considerably higher than those of the *Torrey Canyon* and *Ocean Eagle* incidents. Several reasons may account for this: (1) the flow rate of oil was underestimated, (2) the flow rate continued over a period of several months, necessitating repetitive cleanup of beaches, and (3) the removal of some 3,000 tons of storm debris (unrelated to the spill) added to the overall costs.

APPENDIX B

BEACH CHARACTERISTICS

Two factors important to the operation of heavy equipment on beaches are the slope of the beach and particle size distribution of the sand grains, since both affect the trafficability of equipment.

The relationship between sand grain diameter and the slope of a beach face for an exposed beach is shown in Fig. B-1. This relationship is valid only for a relatively static beach face. The size of the sand grains on a beach also vary across a beach. The grain size of sand decreases generally along the beach profile as the water depth increases until depths are reached at which normal wave currents do not contact bottom and are incapable of moving bed material. The coarse material is usually found in the tidal zone seaward to the vicinity of the plunge point of waves.[40]

The slope of the beach would be less steep for an eroding beach and steeper for a beach that is growing. In addition, the slope of a beach face is influenced by protection from wave action.

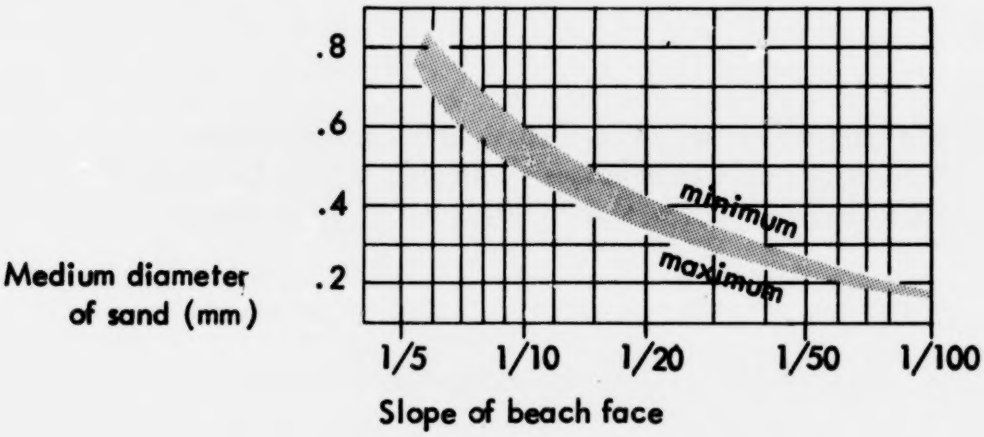
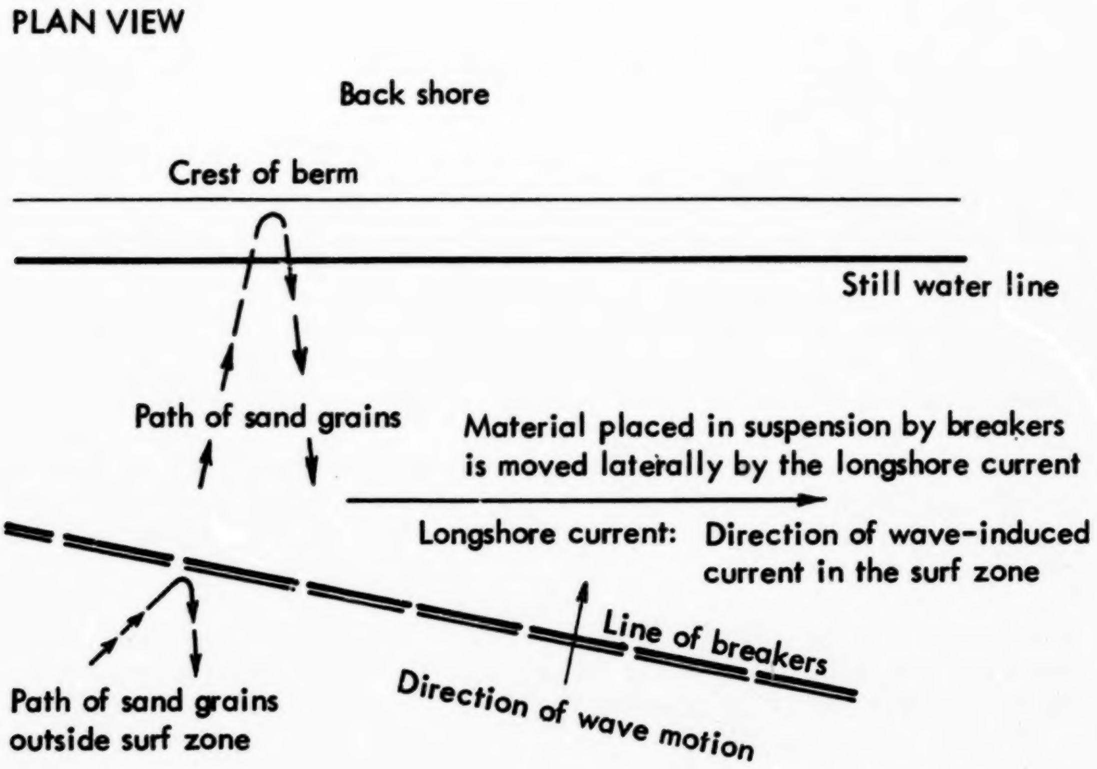


Fig. B-1. Relationship Between Sand Size and Beach Face Slope at the Mid-Tide Zone on Exposed Beaches[41]

Waves that do not strike a beach face perpendicularly will cause littoral transport and a drift of littoral material. Figure B-2 is a plan view illustrating the lateral movement of sand along a beach. It is this action that results in the development of sand spits such as the one formed in the Santa Barbara Harbor and those down the Oregon coast. The littoral drift is also sometimes responsible for the permanent loss of sand from beaches whose source of supply has declined.


PLAN VIEW
Back shore
Crest of berm
Still water line
Path of sand grains
Material placed in suspension by breakers is moved laterally by the longshore current
Longshore current: Direction of wave-induced current in the surf zone
Line of breakers
Direction of wave motion
Path of sand grains outside surf zone

Bed load moves up or down coast in a zigzag pattern.
Movement in all three zones illustrated is in a direction and at a rate dependent on the longshore component of wave energy.

SOURCE: Ref. 41.

Fig. B-2. Longshore or Lateral Movement of Littoral Drift

Oil pollution upon a beach may alter the balance of the beach face. In the Torrey Canyon incident, oil-contaminated beaches which were treated with detergent eroded faster than those beaches not treated. Further, it may influence the rate of littoral drift. Similarly, deposits of oil can be covered by sand that drifts from a clean area. Or, as seen in Santa Barbara, old oil deposits can become uncovered and cause a nuisance, either where they had been originally deposited or by drifting to previously clean beaches. Essentially no quantitative information is available on these effects.

BEACH USAGE AND ACCESSIBILITY

The two most important uses of beaches are recreation and commercial fishing.[42] Oil pollution has a different effect on each. A light amount of oil pollution on a beach, such as that resulting from offshore seeps, probably has little or no effect on marine life or on commercial fishing. The deposits from these seeps, however, represent a continuing nuisance to recreational users of the beach. According to Dennis,[11] 5 oz or more of oil pollutants per 100-ft stretch of beach is likely to seriously inconvenience bathers and beach users. On the other hand, a sudden heavy deposit of oil will interrupt the recreational use of the beach for the duration of the polluting event plus the interval required to clean the beach. Such a serious spill on a major recreational area, such as Long Island or Los Angeles, could result in millions of dollars lost through decreased use by recreational visitors alone.[42] Such a polluting event could have effects on marine life and could upset the ecological balance.

Beaches of high recreational value are usually readily accessible to vehicular traffic. Many of the California pocket beaches, however, have parking lots above the cliffs and only foot trails leading to the beaches. Generally, those beaches having high value can be assumed to have relatively good accessibility to motorized vehicles. If required, adequate accessibility to most beaches for the movement of beach-restoration equipment can be provided in a very short time by the construction of temporary roads or by the use of landing mats to traverse very loose dry sandy areas.

APPENDIX C

SOURCES OF SHORELINE OIL POLLUTION

The major sources of shoreline oil pollution include:

- Petroleum seepages from natural sources.
- Sudden and uncontrolled discharges from offshore oil production or transfer facilities.
- Oil releases from ocean shipping, accidentally or during cleaning and flushing of oil tanks at sea.
- Spillage from onshore and harbor facilities.

Of these sources, the natural seepages and those associated with spillage from onshore harbor or at-sea cleaning of oil tanks represent a chronic or continuing pollution problem, while the sudden and uncontrolled releases from offshore oil production facilities or from accidents involving oil tankers represent acute, relatively short-lived sources of shoreline oil pollution.

NATURAL SEEPAGES

Natural seepages of oil substances (sometimes called tarry materials) are a common occurrence along the Gulf Coast and a portion of the California coast. Hilderbrand and Gunter[43] surveyed the Gulf Coast for oily deposits on the beach and identified many offshore seepages. The greatest concentration of oil substances on California beaches, according to Mertz,[44] appears to be in the vicinity of Coal Oil Point, just a few miles west of Santa Barbara. Other areas are in the vicinity of Redondo Beach. These deposits are attributed by Mertz to nearby underwater oil seeps. Mertz notes that the quantity of oily deposits varies considerably from day-to-day at any one location and varies from north to south. Factors that may be of importance are the season, tide, temperature, and wind. The nature and location of natural oil seeps in Santa Barbara Channel are under study at the present time by the Hancock Foundation, University of Southern California.

OFFSHORE OIL PRODUCTION FACILITIES

The drilling of offshore oil wells represents the largest threat to adjacent coastlines. As stated previously, some 8,000 offshore wells have been drilled since 1954, with 8 of them involved in oil blowouts and 17 in gas blowouts. The Santa Barbara incident was the most serious.

Figure C-1 shows the locations of offshore oil production sites that are presently in operation and concession sites that have been approved or are pending. As seen, present sites are concentrated off the southern California coastline, off the Texas-Louisiana coastline, and in Cook Inlet, Alaska. However, drilling sites are projected for the

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northeastern coastline. Other statistical data relative to offshore oil wells as a source of oil pollution are summarized in a report on pollution to the President.[2]

OCEAN SHIPPING

The shipping of petroleum products and crude oil by tankers is increasing rapidly, and the present trend is toward the use of very large ships. By the end of 1975, Petroleum Economics Limited[45] estimates that 475 tankers having 100,000 dead weight tons or more capacity each, will constitute over half the world's tanker fleet (the Torrey Canyon, for instance, was 118,000 DWT). Ships as large as 300,000 DWT are now under construction.[45]

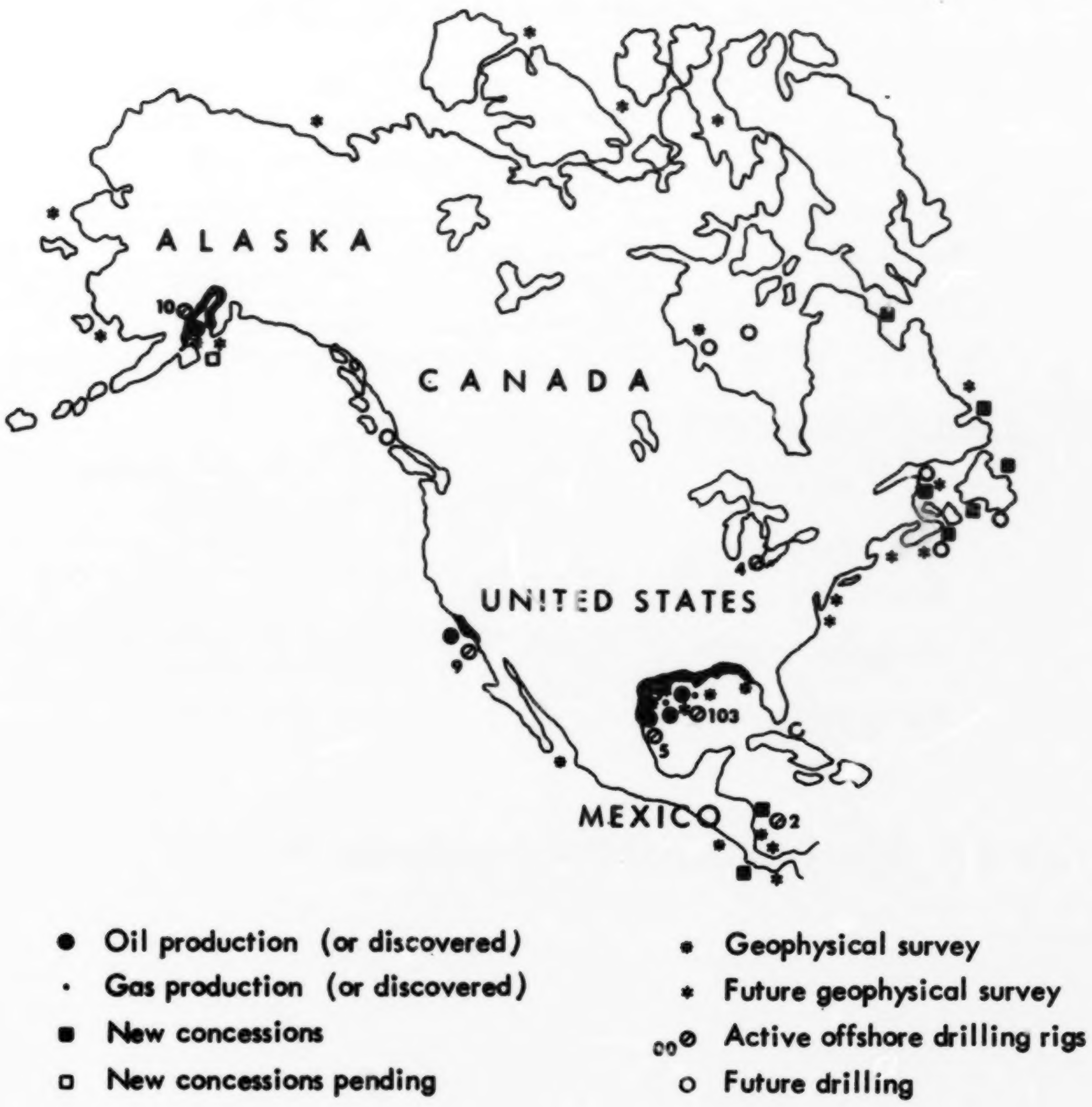
The tankers being designed and built have much larger capacities than today's average operating tanker. However, the crew size of these large tankers will be approximately the same as today's smaller tankers. The large, low-powered super tankers have enormous momentum. They require an estimated 10 miles to stop from full speed if engines are shut off, and they require 3 miles to stop if engines are reversed.

Due to conditions of size, momentum, and vulnerability, the probability of a heavy oil escape from a tanker accident is very real. World oil movements of importance to the continental United States are summarized in Table C-1.

World War II tankers sunk off the east coast of the United States represent a pollution source somewhat similar to natural seepages. The U.S. Coast Guard has surveyed the area where these tankers were sunk and examined selected tankers. Their report[46] indicates that the World War II sunken tankers are not a significant source of oil pollution to the American coastline.

ONSHORE AND HARBOR FACILITIES

Principal sources of oil pollution from onshore and harbor facilities include: (a) spillage of oil during loading and unloading operations; (b) leaky barges, oil storage tanks and pipelines; (c) spillage from various shore installations, refineries, railroads, and various industrial plants. This source of oil pollution is a chronic one that has already destroyed the usefulness of some recreational beaches near large shipping ports and near large refineries.[47] These sources of pollution will probably become less important on an absolute scale as a result of technological improvements, legislative action, and more intensive operator training. Oil-pollution incidents in harbors caused by shipping accidents or the breaking of submarine oil piplines have not proved to be a serious contributor to the oil-pollution problem.


ALASKA
CANADA
UNITED STATES
MEXICO
10
4
9
103
5
2
● Oil production (or discovered)
• Gas production (or discovered)
■ New concessions
□ New concessions pending
* Geophysical survey
* Future geophysical survey
○○⊘ Active offshore drilling rigs
○ Future drilling

SOURCE: Oil & Gas Journal, May 12, 1969.

Fig. C-1. Offshore Oil Production Operations

Table C-1

OIL MOVEMENTS TO MAJOR U.S. PORTS

TO WEST COAST U.S. FROM	MILLION METRIC TONS (Per Year)
Latin America	3
Gulf Coast	3
Near East	10
Far East	3
TO EAST COAST U.S. FROM	
Latin America	22 to New England 84 to South
Gulf Coast	88
Near East	10
Africa	5 to Northeast 5 to South
North Africa	3 to South

Source: International Petroleum Encyclopedia, 1969, p. 8

APPENDIX D

DETAILED TEST DATA OF PHASE I PRELIMINARY EVALUATION TESTS

The following tables summarize data taken while evaluating equipment during the Phase I preliminary evaluation tests on the various beaches.

Included are descriptions and locations of each beach test area, the equipment tested, the type of operation performed, detailed data on each test, including depth of cut, width of cut, length of cut, material removed, area cleaned, time of operation, and cycle time, where applicable, and comments on the performance of the equipment.

Table D-1

DATA SUMMARY

BEACH: TUNITAS
Beach Condition: Tidal zone, wet, hard-packed, fine-grained sand
Equipment: CAT 12 Motorgrader
Gear: Second
Length of Run: 100 ft
Date: November 14, 1969

TEST NO.	OPERATION	ANGLE (deg)	CUT WIDTH	CUT DEPTH (in.)	TIME (sec)	MAIN WINDROW HEIGHT (in.)	MAIN WINDROW WIDTH	AREA CLEANED (sq yd)	VOLUME REMOVED (cu yd)	SPEED (mph)	COMMENTS
C-1-1	Three passes over 100' ×30' test area with different blade angle each pass. 1" and ½" depths of cut.	40	9' 5"	1	30	8.5	2' 4"	104	2.9	2.3	Smaller blade angles (40°) cause greater spillage around leading edge of blade. Larger blade angle (50°) causes little or no spillage
C-1-2		50	8' 7"	1	30	8	2' 6"	93	2.6	2.3	
C-1-3		55	7' 2"	0.5	30	7	1'11"	80	1.1	2.3	
C-2-1	Three passes over 100' ×30' area. Blade angle (60°). Large windrow. 1" depth of cut.	60	6' 8"	1	27	6.5	1' 9"	74	2.06	2.5	Blade control difficult at 60° angle. By third pass sand build up caused major spillage at leading edge on last 30' of run.
C-2-2		60	6'11"	1	27	10	2' 8"	77	2.14	2.5	
C-2-3		60	6'10"	1	27	15	3' 6"	76	2.1	2.5	
TOTAL			16' 5"	1				183	5.1		
C-3-1	Three passes over 100' ×30' area. Blade angle (50°). Large windrow. 1' depth of cut.	50	8' 6"	1	30	6	2' 5"	94	2.6	2.3	Almost no leading edge spillage. Sand build up but no excessive spillage.
C-3-2		50	8' 6"	1	27	18	3'	94	2.6	2.5	
C-3-3		50	8' 6"	1	27	18	4'	94	2.6	2.5	
TOTAL			20'10"	1				232	6.35		

Table D-2

DATA SUMMARY

BEACH: TUNITAS
Beach Condition: Tidal zone, wet, hard-packed, fine-grained sand
Equipment: IH E-200 Motorized Elevating Scraper
Gear: First
Date: November 17, 1969

TEST NO.	OPERATION	CUT LENGTH (ft)	CUT WIDTH	CUT DEPTH (in.)	TIME (sec)	MATERIAL IN BOWL EST (cu yd)	AREA CLEANED (sq yd)	VOLUME REMOVED CALC (cu yd)	SPEED (mph)	COMMENTS
D-1-1	Three passes over 100' ×30' area. Various cutting depths.	100	8' 2"	4	27	9	91	12.2	2.5	Less spillage around scraper bowl edge when thinner (less than 2") cut is made. Excessive spillage when bowl closed and filled.
D-1-2		100	7'11"	2	25	6	88	4.9	2.7	
D-1-3		90	8'	2	20	5	80	4.4	3.4	
TOTAL		96	20' 3"				216	16		
F-1-1	Four passes at various depths of cut (1 to 4") picked up kelp, debris and sand	106	8'	2.5	35	8	94.2	6.5	2.1	Picked up debris and kelp leaving clean cut with minimum amount of spillage.
F-1-2		180	8'	1	–	9	160	4.3	–	
F-1-3		158	8'	4	60	9	140	15.5	1.8	
F-1-4		160	8'	–	35	9	142	–	3.1	

Table D-3

DATA SUMMARY

BEACH: TUNITAS
Beach Condition: Tidal zone, wet, hard-packed, fine-grained sand
Equipment: CAT 12 Motorgrader (Blade angle 50°),
IH 175B Front End Loader
IH E-200 Motorized Elevating Scraper
Length of Run: 100 ft
Date: November 17, 1969

TEST NO.	OPERATION	CUT		TIME	EQUIPMENT TYPE	MAIN WINDROW		AREA CLEANED	VOLUME REMOVED	SPEED	COMMENTS
		WIDTH	DEPTH (in.)	(sec)		HEIGHT (in.)	WIDTH (in.)	(sq yd)	(cu yd)	(mph)	
E-1-1	Three passes over 100' ×30' area with motor-grader forming one large windrow. Windrow removed by elevating scraper.	9'	1	25	Motor-grader	7	20	99		2.7	Windrow formed by motorgrader picked up by scraper worked well. Scraper took cut deeper than 2" and some spillage occurred on edges of scraper bowl.
E-1-2		15'6"	1	20	Motor-grader	8	31	171		3.4	
E-1-3		27'	1	20	Motor-grader	9	40	300		3.4	
E-1-4		8'	2	20	Scraper			300	8.1	3.4	
G-1	Three passes over 100' ×30' area with motor-grader forming one large windrow. Windrow removed by front end loader			20	Motor-grader					3.4	Excessive spillage around edge of front end loader bucket when picking up windrow. Front end loader tracks ripped up beach badly.
G-2				25	Motor-grader					3.4	
G-3				25	Motor-grader	12	42	300		2.7	
G-4				480	Front End Loader (2 yd)						

Table D-4

DATA SUMMARY

BEACH: TUNITAS
Beach Condition: Tidal zone, wet, hard-packed, fine-grained sand
Equipment: IH E-200 Motorized Elevating Scraper
Date: November 19, 1969

TEST NO.	OPERATION	CUT LENGTH (ft)	CUT DEPTH (in.)	CUT WIDTH	TOTAL TIME FOR OPERATION (min)	GEAR	SPEED PER PASS AVG (mph)	AREA CLEANED (sq yd)	VOLUME REMOVED CALC (cu yd)	SAND REMOVED (sq yd /min)	SAND REMOVED (cu yd /min)	COMMENTS
H-1-1*	Long pass to fill bowl, 200' to dump area, returned for 3 passes per trial. Different gears tried to find best operating speed.	100	2.5	21'3"	4:20	1st	–	236	16.3	54.5	3.8	Difficulty in controlling the cut and spillage in second gear. Better control in first gear with less spillage.
H-1-2**		250	2	20'6"	6:50	1st	3.4	569	31.3	83.3	4.6	
H-1-3**		250	1.5	27'	4:50	2nd	4.6	750	30.7	155.2	6.4	
L-1-1	Three passes over 100' ×30' test area. Test area covered with straw.	100	1.5	8'	0:25	1st	2.7	88.6	3.7	–	–	Little difficulty picking up sand-straw combination. Straw appears to cut down spillage when scraper is operating and when bowl is raised and closed.
L-1-2		100	1	8'	0:20	1st	3.4	88.6	2.5	–	–	
L-1-3		100	1	4'6"	0:20	1st	3.4	50	1.4	–	–	
TOTAL		100	1-1.5	20'				222	7.7			

* No dumping in between 100-yd passes.
** 100 ft to dump

Table D-5

DATA SUMMARY

BEACH: TUNITAS
Beach Condition: Tidal zone, wet, hard-packed, fine-grained sand
Equipment: CAT 12 Motorgrader (Blade angle 50°),
IH E-200 Motorized Elevating Scraper
Date: November 19, 1969

TEST NO.	OPERATION	EQUIPMENT TYPE	CUT LENGTH (ft)	CUT WIDTH*	CUT DEPTH* (in.)	GEAR	TOTAL TIME FOR OPERATION (min)	SPEED PER PASS AVG (mph)	AREA CLEANED (sq yd)	SAND REMOVED (cu yd)	SAND REMOVED (sq yd/min)	SAND REMOVED (cu yd/min)	COMMENTS
J-1-1	Three passes over 200' x30' area with motorgrader forming large windrow. Windrow removed by elevating scraper	Motor-grader	200	28'	1	2nd	2:43	4.1	622	17.3	226	6.3	Motorgrader most effective operating in second gear. Poor control of blade in third gear. Motorized elevating scraper most effective in first gear.
J-1-2		Elevating Scraper	150	4'4"	22	1st	1:55	1.1	72	21.5			
J-1-3		Motor-grader	200	28'	0.5	1st	4:00	2.6	622	8.7	155	2.2	
J-1-4		Elevating Scraper	100	4'	10	1st	1:30	2.3	44	16.1		4.1	
J-1-5		Motor-grader	200	30'4"	0.5	3rd	2:32	6.2	674	9.3	266	3.7	
J-1-6		Elevating Scraper	120	3'6"	10	2nd	1:10	2.3	46.6	16.4		5.5	
J-1-5+6		Combination	120				4:10		674	6.4	164	1.6	
K-1-1	Three passes over 100' x30' area with motorgrader forming large windrow. Windrow removed by elevating scraper. Area covered with straw.	Motor-grader	100	8'	1	2nd	0:23	3.0	89	2.5	232	6.5	Combination picked up sand-straw easily. Straw appeared to give sand more body. Less spillage occurred around edges of scraper bowl.
K-1-2		Motor-grader	100	8'	1	2nd	0:20	3.4	89	2.5	267	7.5	
K-1-3		Motor-grader	100	8'	1	2nd	0:18	3.6	89	2.5	281	7.9	
TOTAL				27'	1				300	8.3			
K-1-4		Elevating Scraper	70	4'8"	23	1st	0:22	2.2		6.6		18	
K-1-5		Elevating Scraper	30			1st	0:15	1.4		5.0		20	

---

* For scraper this is the height of windrow + width.

Table D-6

DATA SUMMARY

BEACH: HALF MOON BAY HARBOR
Beach Condition: Backshore area, loosely packed, coarse-grained sand
Equipment: CAT 12 Motorgrader,
CAT 10 Motorized Scraper,
IH E-200 Motorized Elevating Scraper
Date: November 24, 1969, "M" Tests
November 25, 1969, "O" Tests

TEST NO.	OPERATION	EQUIPMENT TYPE	CUT LENGTH (ft)	CUT WIDTH (ft)	CUT DEPTH (in.)	MAIN WINDROW WIDTH (ft)	MAIN WINDROW HEIGHT (in.)	TIME SINGLE PASS AVG (sec)	TIME CYCLE (min)	SPEED SINGLE PASS (mph)	AREA CLEANED (sq yd)	VOLUME REMOVED (cu yd)	COMMENTS
M-1-1	Three passes over 100' x30' area with motorgrader forming one large windrow. Windrow removed by elevating scraper.	Motor-grader	100	27.2	1	3	6	18	1:15	3.8	300	8.3	On soft sand, great degree of spillage around grader leading edge and scraper bowl.
M-1-2		Elevating Scraper	100	8	1.5			30		2.3			
O-1-1	Motorized elevating scraper and motorized scraper making one pass for comparison of operation.	Motorized Scraper	50	8.5	3.5			15		2.3	47.2	4.6	The motorized scraper operated for 50', picked up 4 cu yd of sand and became immobilized. The motorized elevating scraper had no difficulty.
O-1-2		Elevating Scraper	100	8	3.5			30		2.3	89	8.6	

Table D-7

DATA SUMMARY

BEACH: HALF MOON BAY HARBOR
Beach Condition: Tidal zone, wet, firm-packed, medium-grained sand
Equipment: CAT 12 Motorgrader,
CAT 10 Motorized Scraper,
IH E-200 Motorized Elevating Scraper
Date: November 24, 1969, "M" Tests
November 25, 1969, "O" Tests

TEST NO.	OPERATION	EQUIPMENT TYPE	CUT LENGTH (ft)	CUT WIDTH (ft)	CUT DEPTH (in.)	MAIN WIDTH (ft)	WINDROW HEIGHT (in.)	TIME SINGLE PASS AVG (sec)	TIME CYCLE (min)	SPEED SINGLE PASS (mph)	AREA CLEANED (sq yd)	VOLUME REMOVED CALC (cu yd)	VOLUME REMOVED OBS (sq yd /min)	VOLUME REMOVED CALC (cu yd /min)	COMMENTS
M-2-1	Three passes over 100' ×30' area with motorgrader forming one large windrow. Windrow removed by elevating scraper	Motorgrader	100	27	0.5	3.3	9	19	2:15	3.6	300	4.2	133	1.9	Much less spillage from motorgrader and elevating scraper on firm sand.
M-2-1		Elevating Scraper	100	8	0.5			31	1:11	2.2				3.5	
TOTAL			100	27	0.5				3:26		300		87.4	1.2	
M-3-1	Motorized elevating scraper picking up kelp along surf line	Elevating Scraper	200	8	0.5			51		2.7	178	2.5	209	2.9	Motorized elevating scraper had no difficulty pick'ng up kelp and seaweed.
M-3-2		Elevating Scraper	290	8	0.5			74		2.7	258	3.6	209	2.9	
O-1-3	Motorized elevating scraper and motorized scraper making one pass for comparison.	Motorized Scraper	60	8.5	3			24		1.7	57	4.7	142	11.7	The motorized scraper operated for 60' and became immobilized. Elevator scraper had no difficulty operating.
O-1-4		Elevating Scraper	190	8	0.5			45		2.9	169	2.4	225	3.2	

Table D-8

DATA SUMMARY

OIL CONTAMINATED BEACH CLEANUP
Oil Used: 5 gallons - aged 1 week
Equipment: CAT 12 Motorgrader,
IH E-200 Motorized Elevating Scraper,
Front End Loader - 1.75 cu yd

TEST NO.	OPERATION	BEACH CONDITION	OIL SPREAD DATA			AREA COVERED APPROX (sq yd)	TOTAL TIME FOR REMOVAL (min)	TOTAL AREA CLEANED (sq yd)	SAND REMOVED		COMMENTS
			WIDTH (ft)	LENGTH (ft)	DEPTH of PENETRATION (in.)				(cu yd)	(sq yd /min)	
A-2	Front End Loader used as bulldozer to scrape oil-contaminated sand into pile. Then used as loader to haul material to disposal area.	Backshore area. Dry, loosely-packed, coarse-grained sand.	16	24	0.5	64	55	70	12	1.2	Difficulty in adjusting depth of cut; more sand moved than necessary. Spillage excessive around blade edges
B-1	Front End Loader using bucket as scraper removing oil-contaminated sand to disposal area.	Tidal zone, wet, loosely-packed, coarse-grained sand	16	31	0.5	45	55	50	12	0.9	4-in-1 bucket as scraper and loader made deeper cut than necessary. Tracks of vehicle tore up beach considerably, pushed surface layer of contaminated oil deeper into beach.
N-1	Motorgrader scraping oil-contaminated sand into windrow. Elevating scraper removing windrow to disposal area.	Tidal zone, wet, firm-packed, medium-grained sand.	16	35	0.25	60	5	264	3.5	53	Overall operation of grader/scraper combination effective. Front wheels of motorgrader pressed thin layer of oil-contaminated sand deeper into beach. Minimum amount of clean sand was removed compared to the front end loader when tested under similar circumstances.

APPENDIX E

DESIGN OF LABORATORY APPARATUS FOR LEACHING OIL FROM CONTAMINATED BEACH SAND FOR ANALYTICAL PURPOSES

An apparatus for use in the laboratory to quantitatively remove and recover the oil contained as oil contaminant in samples of beach sand up to about 100 lb in weight, or about 3/4 cu ft in volume, was constructed. It was decided that the leaching should be done as a batch process.

In the batchwise leaching process, the solvent and material being leached are brought together for an appropriate time, after which the solvent is drained off and the process repeated. In each leaching cycle, an amount of solvent must be added to fill the void spaces of the sample, since otherwise some parts of the interior of the sample will not be reached by solvent, and hence not leached in that cycle.

It was determined experimentally that an amount of carbon tetrachloride, as solvent, equal to about one-third the volume of sand is needed to fill the void spaces of the sand being used if the sand is dry. About 0.25 cu ft of carbon tetrachloride will be required for each cycle of the batchwise leaching process.

The essential operations in the batchwise process are given in Fig. E-1.

It is evident that very nearly the entire 0.25 cu ft of solvent carbon tetrachloride must be evaporated and condensed again during each cycle. It was found experimentally, using about 2 lb of agglomerated oil-sand mixture, that six cycles of leaching was a bare minimum to get out most of the oil, even though the mixture of sand and solvent was stirred to improve contact in each cycle. About 12 cycles is a more realistic number under routine conditions.

If this number of cycles is to occur in a reasonable length of time (30 min to 1 hr), there must be a cycle about every 5 min. Thus, the solvent stripper must be capable of evaporating about 0.25 cu ft of carbon tetrachloride solvent each 5 min, or at a rate of 0.05 cu ft/min as a minimum. To allow some design leeway, this figure has been raised to 1/14 cu ft or 7 lb of carbon tetrachloride per minute or 420 lb/hr .

The heat required to bring this amount of liquid carbon tetrachloride to its boiling point is:

$$420 \frac{\text{lb}}{\text{hr}} \times 0.201 \frac{\text{Btu}}{\text{lb}/^{\circ}\text{F}} \times (170-70)\ ^{\circ}\text{F} = 8440 \frac{\text{Btu}}{\text{hr}}$$

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The heat required to vaporize the carbon tetrachloride is:

$$420 \frac{\text{lb}}{\text{hr}} \times 83.5 \frac{\text{Btu}}{\text{lb}} = 35{,}100 \frac{\text{Btu}}{\text{hr}}$$

Total heat input rate to vaporization would, therefore, be:

$$35{,}100 + 8440 = 43{,}540 \frac{\text{Btu}}{\text{hr}} = 12.76 \text{ kilowatts.}$$

This figure is a maximum in that the solvent will not return to the stripper at room temperature, but rather at some temperature between room temperature and the solvent boiling point. The heat required to vaporize the solvent, 35,100 Btu/hr, would represent a minimum heat required for vaporization.

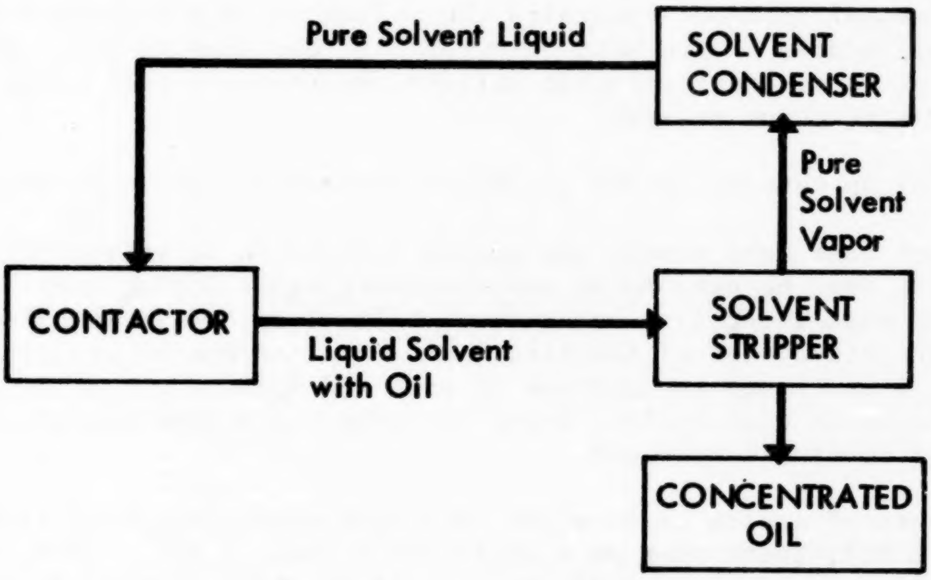
Pure Solvent Liquid
SOLVENT CONDENSER
Pure Solvent Vapor
CONTACTOR
Liquid Solvent with Oil
SOLVENT STRIPPER
CONCENTRATED OIL

Fig. E-1. Block Diagram of Batch Leaching Process

DESIGN OF SOLVENT STRIPPER AND CONDENSER

Vaporization in the stripper was driven by a temperature gradient across the heat transfer surface of modest proportions so that temperatures higher than about 210°F did not occur anywhere in the system. In this way, thermal decomposition of both solvent and oil was kept to a negligible minimum. The evaporator surfaces, which consisted of coiled

5/16 in. copper tubing, were heated with water at or near its normal boiling point, supplied from a small boiler, designed for residential heating, having a maximum output of 64,000 Btu/hr. The boiler operated at a pressure of 20 psig, so that water temperatures in a range up to 220°F were available, if needed.

The method given in the Chemical Engineers' Handbook for calculating transfer area in evaporators applies a heat transfer coefficient of 350 Btu/hr/ft^2/°F for all occasions. If an average water temperature of 190°F (halfway between 170°F, the boiling point of carbon tetrachloride, and 210°F) is assumed, the heat transfer area is obtained as follows:

$$A = \frac{43{,}540}{(190-170) \times 350} = 6.22 \text{ sq ft}$$

A surface area of this size is obtained on the exterior of 76 ft of 5/16-in.-diameter tubing.

To furnish 43,540 Btu/hr from hot water with a 40°F temperature drop in the water requires 1,088 lb of water per hour, or 2.17 gal/min, to be pumped through the coil of the solvent stripper. The stripper coil was fabricated of two 5/16-in. tubes (0.248 in. ID) in parallel, rather than being wound from a single tube, because the pressure drop required to move 2.17 gal/min of hot water through the stripper was thereby reduced to approximately 40 psi, a pressure easily provided by an inexpensive type of gear pump. In each of the parallel branches, 50 ft of tubing was used.

By a similar kind of calculation, using a heat transfer coefficient of 250 Btu/hr/ft^2/°F, as recommended in Chemical Engineers' Handbook, and temperature difference of 50°F with heat flux of 35,100 Btu/hr, it is found that 34 ft of 5/16-in. tubing is needed as a minimum in the condenser.

Both the solvent stripper and condenser were made from sections of industrial Pyrex glass pipe of 4-in. ID. Glass pipe allowed observation of both the stripping and condensation processes as an aid in adjusting heat flows in both processes. The heat transfer coils within the glass pipes were connected through metal end-plates to external sources of heating and cooling water.

DESIGN OF CONTACTOR

A method of contacting that provided rapid breakup of agglomerated oil-sand mixtures into the solvent, together with the efficient use of the solvent in each cycle, was that of tumbling the contaminated sand sample in a rotating drum as the solvent cycled through it. Fortunately, equipment was commercially available at modest cost to perform this operation. A 1-3/4-cu-ft concrete mixer was mechanically complete for this purpose. The only additions required were a cover, clamped onto the discharge opening of the drum to prevent escape of vaporized solvent, with suitable connections for admission and removal of solvents, and a device to automatically drain out the solvent at the end of each cycle. A simple switching system controlled the cycling of the solvent.

These additions to the mixer and its mode of operation in contacting solvent with contaminated sand are illustrated in Fig. E-2.

In addition to the cover for the drum, a steel frame was welded to the yoke supporting the drum. This frame supported the solvent inlet tube, which remains stationary as the drum rotates. The frame also provides a leverage by which the motor-brake system pivoted the drum on a horizontal axis at the end of each cycle. The solvent inlet tube leaves the steel frame at the horizontal pivot axis, being connected thence to the solvent condenser discharge via a length of plastic tubing.

OPERATING PROCEDURE

To start an extraction, the oil-contaminated sample was placed in the contactor and the cover secured on the drum. About 2 gal. of carbon tetrachloride was placed in the reservoir below the contactor and about 2 gal. in the mixer drum. The water heater for the solvent stripper was started and the hot-water pump turned on. Cold tap water was started flowing in the condenser. When the return water from the stripper was hot, as indicated by its thermometer, the pump, feeding solvent from the reservoir to the solvent stripper, was turned on and operation of the mixer started.

The flow of oil extract from the reservoir to the stripper was controlled by a valving system that included a bypass loop around the pump. By adjustment of a valve in the bypass loop and a valve in the line downstream from the pump, any desired fraction of the pump throughput could be fed into the stripper, the remainder being recirculated through the bypass loop. The extract flow rate to the stripper was adjusted upward until the capacity of the stripper was reached. This condition was indicated by flooding of unstripped extract at the bottom of the stripping column, in which an undesirably large amount of solvent entered the oil extract receiver.

Once a stable relation between flow of heat and extract into the stripper was established, operation was largely automatic. Completion of the extraction of oil from a sample was indicated when solvent discharged from the mixer became clear.

The stripped extract from each sand sample contained oil dissolved in approximately 1-1/2 gal. of carbon tetrachloride solvent. The stripped extract from each sample was weighed, and an aliquot taken for analysis. A weighed sample of the aliquot was placed in a previously weighed watch glass. Carbon tetrachloride contained in the sample was allowed to evaporate at room temperature until the rate of loss of weight of the sample was negligible. This occurred within a period of about 3

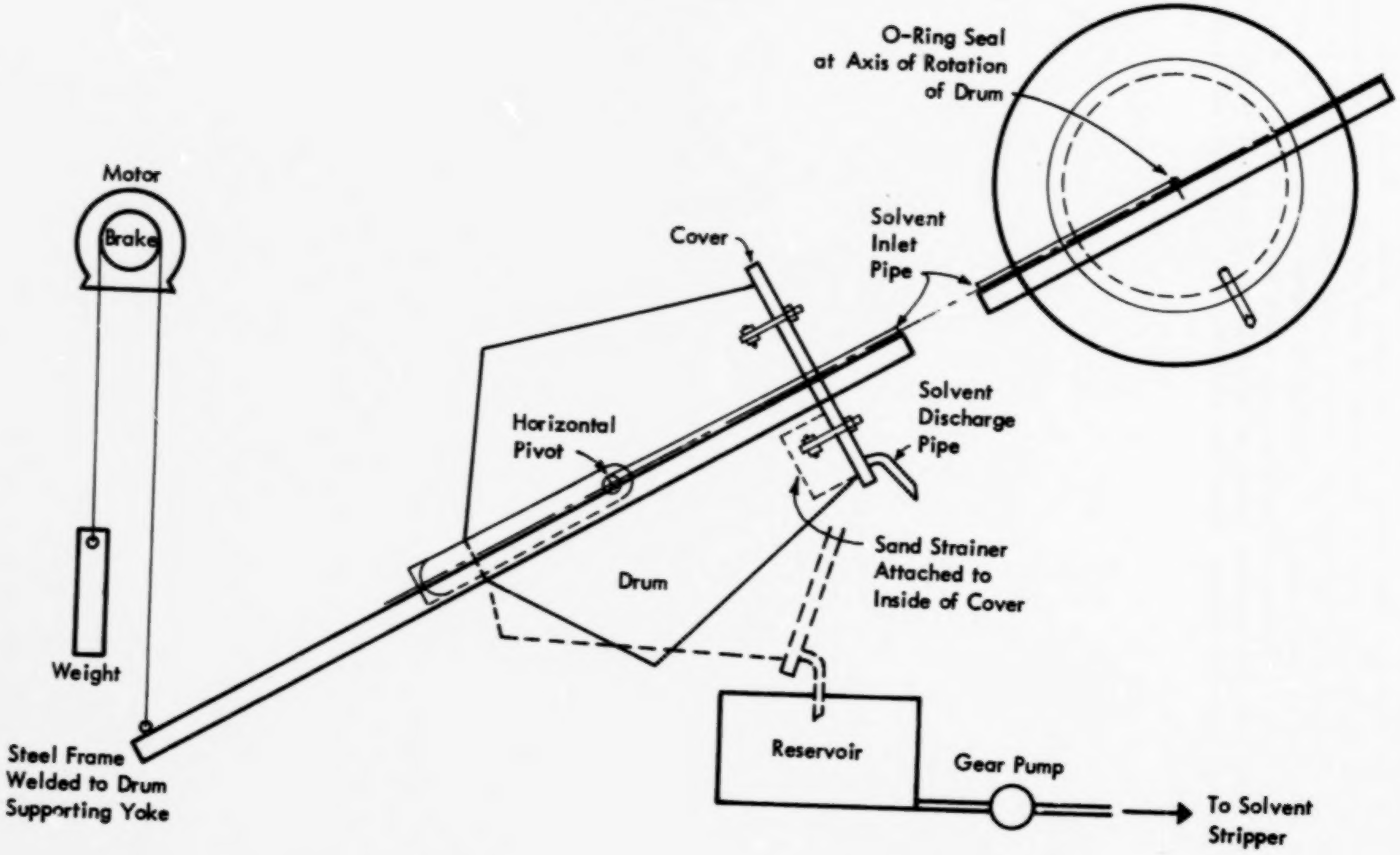
O-Ring Seal
at Axis of Rotation
of Drum
Motor
Brake
Cover
Solvent
Inlet
Pipe
Horizontal
Pivot
Solvent
Discharge
Pipe
Sand Strainer
Attached to
Inside of Cover
Drum
Weight
Steel Frame
Welded to Drum
Supporting Yoke
Reservoir
Gear Pump
To Solvent
Stripper

Fig. D-2. Modification of Cement Mixer for Use as Solvent Contactor days. The weight of oil contained in the sample was taken as the weight of the residue remaining in the watch glass. This method of analysis was made possible by the fact of the oil had become weathered before and during its application to the beach sands, so that it contained negligible quantities of components whose volatility was comparable to that of carbon tetrachloride. The weight ratio of oil to extract found in the sample, when multiplied by the total weight of stripped extract recovered, gave the weight of oil recovered from each sand sample.

APPENDIX F

DOCUMENTATION OF BEACH RESTORATION OPERATIONS: PROPOSED DATA REQUIREMENTS

To evaluate the manpower and equipment costs associated with beach restoration operations, a review of recent oil-pollution/beach-contamination incidents was conducted as part of Phase I. It was very quickly determined that there has been little to no effort directed towards the systematic collection of data needed to accurately determine the cost and effectiveness of previous beach restoration operations. Generally, only overall costs have been reported, and costs associated with onshore operations could not be separated from the total costs.

A set of data collection sheets has been included in this appendix as an example of the forms to be used by FWQA personnel who become involved in future oil-spill incidents.

As in all operations of this type, photography, both still and motion picture, proves to be invaluable during subsequent analysis of the data. Care must be taken, however, to properly document the photographic effort, i.e., date, time, location, etc.

A sketch or quadrangle map showing beach location and important features, such as breakwaters, groins, roads, and other shoreline installations, would assist in subsequent analysis of the cleanup operation.

BEACH-RESTORATION PROCEDURES
DATA SHEET INSTRUCTIONS

Separate data sheets should be prepared for each separate event, type of beach, variation of beach characteristic, or restoration procedure.

If it is necessary to use more room for entries than that provided on the sheet, use the reverse side of the form.

Identify each separate page by including beach name, its location, and the data at the top.

Section A: Event description - include what spilled, from where, what caused spill (collision, explosion, grounding, pipeline failure).

Section B: This information is pertinent for prediction of weathering effect on contaminant.

Section C: Data in this section will be utilized to assist in the evaluation of the cost and effectiveness of the beach-restoration operation and to correlate trafficability (mobility) factors with equipment type. Sand samples should be taken in both the tidal and back-beach zones for sand grain size determination. If it is necessary to clarify data or obtain additional information, the persons reporting or submitting the data forms will be contacted.

Section D: This section is to be used for equipment actually cleaning the beach and does not include hauling operations. A daily estimate of area cleaned and cost should be recorded. Participating organizations would include the names of agencies, (FWQA, API); companies, (oil companies, private research or consulting firms); contracting firms; local and state authorities which were directly involved in clean-up procedures. The organizations should be listed, where applicable, across the top of the daily record squares. If equipment is under contract, rented or leased, it should be shown as a note under Comments, Observations. If certain equipment is immobilized by a low-bearing beach, this should also be noted. Record all information possible, although partial reporting of data may be all that is available.

Section E: Hauling operations, exclusive of beach cleanup, should be included here. If contaminated sand and debris are hauled to several disposal areas, include specific details on reverse side of form. Participating organizations would include the names of agencies, (FWQA, API);

companies, (oil companies, private research or consulting firms); contracting firms; local and state authorities which were directly involved in sand disposal operations. The organizations should be listed, where applicable, across the top of the daily record squares.

Section F: If a change in type of absorbent or dispersal methods occurs during the 7 days covered by these sheets, but all else remains relatively unchanged, write additional information on reverse of form.

Page 1 of 5

BEACH RESTORATION PROCEDURES

BEACH: Name ______________ Location ______________ Dates ______________

A. DESCRIPTION OF EVENT: ______________

B. OIL CHARACTERISTICS:

1. Date and time of spill: ______________
2. Type of oil: Bunker C, diesel, other ______________
3. Source: tanker, pipeline, platform ______________
4. Amount spilled (est. gallons): ______________
5. Spill stopped or continuing: ______________
6. Initial beach contamination: date ______________ time ______________
7. Physical appearance of oil on beach: hard, tacky, liquid, globs (size), other ______
8. How is beach contaminated: ______________
   continuous film, mixed with debris or straw, puddled, other
9. Subsequent contamination: date ______________ time ______________

C. BEACH CHARACTERISTICS

10. Surface: rocky, sandy, other ______________
11. Surface condition: kelp, debris, litter, clean, other ______________
12. Contaminated zone: tidal, backshore, both ______________
13. Tidal zone: average slope (%) ______________
14. Contaminated area (yds): length ______ width ______ total (sq yds) ______
15. Oil penetration depth (in): maximum ______________ average ______________
16. Grain size (median): tidal zone ______________ backbeach ______________
17. Accessibility to heavy equipment for restoration operations: ______________
    easy, possible, hazardous, can build road, impossible
18. Can beach surface support equipment mobility: yes ____ no ____ can't tell ______

Data reported by: ______________

Submitted by: ______________

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Page 2 of 5

BEACH CLEANUP

BEACH: Name ______________________ Location ______________________ Dates ______________________

D. RESTORATION PROCEDURES

By Day:	1	2	3	4	5	6	7
a. Method used:							
b. Total area cleared							
c. Depth of sand removed (in.)							

d. EQUIPMENT: scraper, motorgrader, front-end loader, bulldozer, other

Type, Make/Model, Size

number used							
$ cost							
number used							
$ cost							
number used							
$ cost							
number used							
$ cost							
number used							
$ cost							
number used							
$ cost							

Comments, Observations:

BEACH: Name ______________________ Location ______________________ Dates ______________________

e. MANPOWER FOR CLEANUP - EQUIPMENT OPERATIONS

Supervisory Participating organizations:

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

Equipment Operators Participating organizations:

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

Laborers Participating organizations:

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

Comments, Observations :

Page 4 of 5

BEACH: Name ________ Location ________ Dates ________

E. OIL-SAND DISPOSAL

a. Procedures used: ramp, conveyor-screening system, hauling, other ________

b. Hauling distance from pickup to disposal: (average) ________

c. Location of disposal site: ________

d. Number of unloading sites: ________

e. HAULING VEHICLES:

By Day:	1	2	3	4	5	6	7
size (cu yd)							
number used							
number of trips							
$ cost							
size (cu yd)							
number used							
number of trips							
$ cost							
size (cu yd)							
number used							
number of trips							
$ cost							

BEACH: Name ______________ Location ______________ Dates ______________

e. MANPOWER FOR DISPOSAL OPERATIONS

Supervisory Participating organizations:

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

Operators/Drivers Participating organizations :

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

Laborers Participating organizations:

By Day:	1	2	3	4	5	6	7
number used							
hours worked							
$ cost							

F. ABSORBENTS USED ON BEACH

Type: chemical, physical, other ______________

Substance: straw, foam, other ______________

Amount used (gal, bales, lb): ______________ $ cost: ______________

Dispersal methods: ______________ $ cost: ______________

Manpower utilized: ______________ $ cost: ______________

BIBLIOGRAPHIC

URS Research Company, The Evaluation of Selected Earthmoving Equipment for the Restoration of Oil-Contaminated Beaches, Final Report, FWQA Contract No. 14-12-811, October 1970

ABSTRACT

Research studies were conducted to evaluate the use of selected earthmoving equipment in oil-contaminated beach-restoration operations and to determine the cost and effectiveness of such equipment. Specifically, the objectives were to:

- Determine modifications and cost required to improve the capacity of selected equipment.
- Develop optimum operating procedures for each method.
- Determine, through field testing, the operating cost of each method evaluated.

These objectives were accomplished in two phases. Phase I: reviewed procedures utilized in previous beach-restoration operations, plus surveyed and evaluated commercially available earthmoving equipment. Phase II: full-scale tests to demonstrate the restoration procedures developed and to determine the efficiency with which each procedure/equipment item collects oil-contaminated material. The flexibility and performance characteristics of the equipment were tested under a variety of beach conditions.

The oil removal effectiveness was greater than 98% for all restoration procedures. The highest effectiveness was achieved using the motorized grader and motorized elevating scraper working in combination. The tracked front end loaders were least effective. On beaches possessing low shear strength, flotation tires or steel-belted half-tracks on the motorized grader and a non-self-propelled elevating scraper with a tracked prime mover should be used. Conveyor-screening systems can be effectively utilized to load oil-contaminated material into trucks or transport to disposal areas, separate oil-sand pellets from clean sand, and partially separate oil-contaminated debris (i.e., straw, kelp, seaweed) from oil-contaminated sand.

KEY WORDS:

Oil Spills
Oil Contamination
Beach Restoration
Earthmoving
Equipment
Costs and
Effectiveness

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Equipment
Costs and
Effectiveness

1 *Accession Number*

2 *Subject Field & Group*

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 *Organization*
URS RESEARCH CO., 155 Bovet Road, San Mateo, California 94402

6 *Title*
THE EVALUATION OF SELECTED EARTHMOVING EQUIPMENT FOR THE RESTORATION OF OIL-CONTAMINATED BEACHES

10 *Author(s)*
James Sartor
Carl Foget

16 *Project Designation*

21 *Note*

22 *Citation*

23 *Descriptors (Starred First)*
Oil spills, Oil contamination, Beach restoration, Earthmoving equipment, Costs and effectiveness

25 *Identifiers (Starred First)*

27 *Abstract*

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Abstractor | *Institution*

WR:102 (REV. JULY 1969)
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